THE

BUILDING AND ORNAMENTAL STONES

OF

GREAT BRITAIN AND FOREIGN COUNTRIES.

FORUM ROMANUM,
Showing the extent of the recent excavations.

Grace E. Russell

A TREATISE

ON THE

BUILDING AND ORNAMENTAL STONES

OF

GREAT BRITAIN AND FOREIGN COUNTRIES,

ARRANGED ACCORDING TO

THEIR GEOLOGICAL DISTRIBUTION AND MINERAL CHARACTER,

WITH ILLUSTRATIONS

OF THEIR APPLICATION IN ANCIENT AND MODERN STRUCTURES.

BY

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PREFACE.

THE Council of the Royal College of Science, Dublin, having assented to a course of lectures to be delivered during the evenings of 1870–71, on Building and Ornamental Stones, I commenced the necessary preparation. Circumstances, however, occurred to prevent the delivery of the course; but while arranging the materials, the subject seemed to grow in interest, and ultimately developed into the form in which it is presented to the reader.

During the progress of my investigations I made the discovery that there is no work in our language especially devoted to the subject itself; a discovery which is the ground on which I now come before the public. Building and Ornamental Stones are, it is true, to a certain extent described in many of the works on masonry, architecture, and engineering, but not in a complete manner, nor with much attempt at scientific arrangement. The

nearest approach to such a work as seems to me to be required is the excellent book of Mr. G. Wilkinson, M.R.I.A., &c., on the 'Ancient Architecture and Practical Geology of Ireland;' and if its author had extended its scope so as to embrace the British Islands, and the more important building materials of other countries, my task would have been unnecessary.

In some of the works on Architecture—such as Gwilt's elaborate volume—and in many scattered Journals of Societies, notices and descriptions of Building and Ornamental Stones are abundantly distributed. We have, also, an admirable French work, 'Technologie du Bâtiment,' in two volumes, by M. T. Chateau, full of correct details regarding the nature and uses of such materials, especially as they are found in France; but while this latter work is in a language differing from our own, and fails to give sufficient details regarding British stones for British readers, the former works are, for various reasons, not easily available.

A great difficulty which at the outset presents itself in arranging materials on a scientific, as well as a practical, basis, is to be found in the absence of a generally received mode of classification of rocks,

and a system of nomenclature founded both on origin and composition. Thanks to the labours of microscopists, and partly in consequence of our increasing knowledge regarding the phænomena attending the origin of rock-masses, we are gradually attaining truer views than once prevailed regarding the basis of classification. The use of the microscope has now come to be regarded as absolutely essential to the determination of the composition of igneous and metamorphic rocks, and in such questions exceeds in value even chemical analysis. As an example of the necessity of microscopic examination, I may mention a case which recently came under my own observation. Amongst certain Silurian strata in Clare Island, off the western coast of Ireland, is a dyke of trap-rock, of a dark and dense appearance, strongly resembling basalt. On submitting a slice to microscopic examination, however, it turned out to be a silicated felstone, which owed its basalt-like appearance to innumerable black crystalline grains of magnetite invisible to the naked eye.

The arrangement which has been adopted in this essay follows to a great degree that of the English edition of B. von Cotta's valuable work, 'Rocks

Classified and Arranged,' which, with Bristow's 'Glossary of Mineralogy,' is an indispensable handbook to every practical geologist.

One of the crying evils of the present day is the erection of ephemeral buildings either for dwelling-houses or other purposes. On the other hand, the superior advantages in the long run of substantial structures scarcely admits of an exception. A city which, like Chicago, has been raised up with mushroom-speed, is laid low by fire in a few hours; while solid buildings of stone are capable of resisting the effects both of fire and time, depending in a greater or less degree on their solidity.

This observation extends to all classes of buildings alike. The cottage of the labourer, or his tenement in a single story or 'flat,' ought to be constructed with a view to decency as well as health; while houses of a higher class, unless constructed with substantial walls, well-fitting doors and windows, sound roofs, and proper drainage, are liable to become constant sources of discomfort and outlay. As regards public buildings, the credit of the whole community is at stake if they are not in keeping with the importance, or commercial prosperity, of the city they are intended to adorn.

If such be the principles which should guide us in the erection of edifices for secular or domestic use, how much more are we bound to take care that those consecrated to the worship of Jehovah should not be unworthy of a destiny so sacred and noble. During the last century, and part of the present, the full appreciation of our responsibility in this respect seems to have been dormant. Now, however, a more proper feeling has been resuscitated; and the House of God, instead of being the last, is generally the first, object of care and veneration.

Such were, apparently, the views of those who, in an age generally unenlightened, devoted all their skill and means to the erection of churches which are objects of admiration in our own day. The motives which impelled men to erect the noble minsters, cathedrals, and parish churches of the twelfth and three succeeding centuries, may not always have been of the purest kind, or free from superstition; nevertheless, the founders and architects had clear ideas of this duty—that we should offer unto God of the best of our substance, and that man should not dwell in 'habitations of cedar' while the House of God was mean in form, or

crumbling into decay. That such a spirit has been happily revived amongst ourselves is attested, both by the restoration of the venerable churches of former days, and the erection of modern ones in a style not unworthy of their sacred purpose; and amongst the foremost of those who have taken a prominent part in this good work are two citizens of this metropolis, whose names will ever be had in remembrance; members of a Church despoiled and cast off by the State, but men of whom any State or any Church might well be proud[1].

EDWARD HULL.

DUBLIN, *July* 1, 1872.

[1] Sir Benjamin Lee Guiness, who restored St. Patrick's Cathedral at a cost of 150,000*l.*; and Mr. Henry Roe, who is now engaged in the restoration of Christ Church Cathedral, Dublin.

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TO

SIR CHARLES LYELL, BART., D.C.L., F.R.S.

MY DEAR SIR CHARLES,

To you, who, amongst the first, encouraged me to undertake the preparation of this little Work, I now heartily inscribe it; as a small acknowledgment of the benefits I have derived from the perusal of your scientific writings, especially your 'Principles of Geology,' and of the uniform friendship with which you have honoured me during many years of my life as a migratory Geologist.

Ever faithfully yours,

E. H.

5th August, 1872.

PART I.

CHAPTER I.

INTRODUCTORY OBSERVATIONS.

The materials used in building and architectural decoration are divisible into two classes, the artificial and the natural; and, as the latter is incomparably superior to the former, artificial materials are only admissible when those offered by nature are beyond the reach of the architect, or the means at his disposal.

The general use of artificial materials has stamped with an aspect of comparative meanness the street architecture of many large cities and towns, such as London itself, together with Dublin, Birmingham, and Manchester; while, on the other hand, the employment of stone in the construction of the dwelling-houses, as well as the public buildings, has imparted to the cities of Edinburgh, Aberdeen, Glasgow, Brussels, Paris, and Rome a character of solidity and beauty which forces itself on the attention of the most careless observers.

a

All persons of taste must, with Mr. Ruskin, deplore the manner in which modern English towns are run up on 'the brick-and-plaster system,' presenting interminable lines of streets, in which every house is an exact counterpart of its neighbour, except perhaps in size, and in which one street resembles another as much as two of the bricks with which they are built. The town of Crewe in Cheshire, built within the last half century, and now containing a large number of inhabitants, is the most perfect specimen of a modern brick town built upon the strictest principles of utility without taste; and yet, that it is possible to make use even of red brick with an eye to beauty, is sufficiently clear from the examples we have in the cities of Chester and Shrewsbury, and the quaint and picturesque old farms and manor-houses which bedeck the shires of Chester and Salop themselves.

In contemplating these monotonous lines of brick walling, the only relief which is afforded to the mind is by the reflection that, owing to the flimsy manner in which they have been built, and the badness of the material itself, they cannot last for a lengthened period; and that they may possibly be replaced by other structures, in which some slight regard for appearance may be exhibited.

I here wish to anticipate the reply, that small

and mean houses are necessary as dwellings for the working classes. Such a defence of the system here condemned is inadmissible in presence of the examples of Glasgow and Edinburgh. By the employment of the system of flats—where each family has its own door in a building common to several—houses of lofty and substantial proportion may be rendered available for persons and families receiving weekly wages. In this way the fine public buildings which are to be found amongst all our large towns would not necessarily present such a frightful contrast to the meaner architecture of the streets; but a fitting harmony of effect would pervade the whole of the buildings, both public and private, of cities and towns. The metropolis of the British Empire itself is a conspicuous example of a city in which structures of the grandest proportions, and of elaborate workmanship, stand in striking contrast to streets of houses without architectural beauty.

It is with those materials which nature has so lavishly supplied that we have here to do; and in the following pages the attempt has been made to deal with them in a manner which, while in accordance with our scientific knowledge, does not overlook their practical application; the illustrations of the application of most of these materials to sculpture and architecture may, it is hoped, in-

terest the general reader, while they may serve as a guide to the architect and sculptor.

Arrangement of the Subject. In arranging the matter treated in this work, I have not followed any very definite order, but rather that which the subject seemed to indicate. Commencing with granite, the noblest of all rocks, I have been naturally led onwards to the allied rocks, such as syenite, porphyry, and from these to other plutonic or volcanic rocks. After these, the metamorphic serpentines and marbles form a transition series through the simpler and rarer ornamental stones into those adapted for building, and of aqueous formation. Other modes of arrangement suggested themselves, such as that of adopting the mineral basis of different rocks; but this plan—though probably more theoretically accurate—would not have proved so easy of reference, or so suitable in an architectural point of view. On the other hand, a purely architectural plan of arrangement appeared to be equally objectionable; as it would have necessitated the arrangement under the general heading of 'freestones' of such rocks as sandstones and oolitic limestones, which both in mineral composition and mode of formation are essentially distinct; while, again, under the head of 'marbles,' crystalline limestones, serpentines, and even granites (often called 'hard marbles') would have been grouped together.

It cannot, indeed, but be considered as matter for regret, that so incorrect a system of nomenclature should still obtain in regard to building and ornamental stones; and as our knowledge of the relations and distinctions between the rocks themselves advances, it should be our endeavour to introduce, and render current, a more exact system of naming as applied to such materials.

Classification of Rocks. The classification of the crystalline rocks—including granitic, plutonic, and volcanic—is confessedly a question of extreme difficulty; and of the systems least open to objection, are that of Dr. Zirkel, who makes the varieties of felspar the basis of division, and that of MM. Durocher and Bunsen, who make the proportions of silica the basis. Without venturing on the question of the comparative merits of these two systems, that of the two eminent physicists just mentioned has the merit of being the more generally available; as it is much easier to come to a conclusion in the case of the generality of these rocks—whether they are rich or deficient in silica—than to judge of the nature of their felspathic bases. Durocher, indeed, from an analysis of a large number and variety of forms, has arrived at the conclusion that the basic rocks (those poor in silica) have been derived from a deeper *magma*, or envelope, within the interior of the earth, than that

of the acidic (or highly silicated) rocks, and that silica holds the same essential place amongst these rocks that carbon does amongst products of vegetation. Whatever may be the intrinsic merits of this theory, it is unquestionable that the arrangement of the plutonic and volcanic rocks into basic and acidic is one extremely valuable as a basis for classification; and the following arrangement and definitions of the rocks is one which the author believes will be found approximately accurate, and useful for purposes of reference in this work. He has received valuable suggestions from Messrs. A. and J. Geikie, Mr. G. H. Kinahan, and Dr. Emerson Reynolds, to which he has given due regard.

General Classification and Definition of Granitic, Plutonic, and Volcanic Rocks, of most frequent occurrence.

IGNEOUS AND METAMORPHIC.

Granitic Group.

(*Acidic—highly silicated.*)

Granite. A ternary compound of quartz, felspar, and mica; crystalline and granular.

(*a*) Often a quaternary compound, from the occurrence of two felspars (orthoclase and oligoclase, or orthoclase and albite) or two micas.

(*b*) Less frequently a quinary compound.

(*c*) *Porphyritic granite;* when containing large distinct crystals of felspar.

(*d*) *Foliated granite;* when presenting a foliated structure, and thus verging into gneiss.

(*e*) *Eurite;* when the mica disappears or becomes very scarce, and the rock is finely crystalline-granular.

Granite may be either intrusive or metamorphic, or both; and sometimes passes into quartz-porphyry, and even felstone.

SYENITE. A ternary compound of quartz, felspar, and hornblende. Syenite may be either metamorphic (Ayrshire), or irruptive.

(*a*) When the free silica disappears, the rock passes into diorite; this variation is not unfrequent.

(*b*) *Syenitic granite,* when, in addition to quartz, felspar, and mica, hornblende appears, as in part of the Sleeve Croob range, Co. Down.

IGNEOUS.

Acidic, generally plutonic, but sometimes volcanic, products of past geological periods.

QUARTZ-PORPHYRY. A rock of a felsitic base with crystalline grains or blebs of quartz.

(*a*) By the disappearance of free quartz, this rock merges into a felstone.

(*b*) By the appearance of mica it merges into a granite.

FELSTONE. A rock of a felsitic base, more or less crystalline, or *apparently* compact, with a smooth conchoidal, or fissile, texture; in colour yellow, grey, green, or reddish, generally weathering white; containing silica 71–81 per cent.

(*a*) *Felstone porphyry;* felstone when containing distinct crystals of felspar.

(*Basic—deficient in Silica.*)

PORPHYRITE. (*Quartzless porphyry.*) Felsitic base of Labradorite or oligoclase, usually of a dark colour, sometimes amygdaloidal, with individual crystals of felspar. Proportion of silica, 59–61 per cent.

(*a*) By the appearance of augite, porphyrite shades into melaphyre.

MELAPHYRE. Dark-coloured, greenish, brownish, or black; formed of felspar, augite, and magnetite intimately associated, and often only to be distinguished under the microscope.

(Melaphyre is the representative amongst the Carboniferous and Permian rocks, of basalt and dolerite amongst the Tertiary ones.)

DIABASE. A rock formed of felspar, augite, and chlorite. Magnetite is generally, or perhaps always, present: in its fresh state diabase is dark green.

Diorite (Greenstone). A crystalline granular rock composed of felspar and hornblende. Magnetite in small opaque crystals is generally present.

(The diorites are generally found as intrusive masses amongst the older Palæozoic formations.)

Minette (Mica-trap). A felsitic base with much mica; distinct crystals of orthoclase, and sometimes of hornblende, are present in some specimens.

(Minette generally occurs in dykes amongst the older Palæozoic rocks.)

TERTIARY AND MODERN VOLCANIC ROCKS.

I. Crystalline.

(Basic.)

Basalt. A micro-crystalline compound of Labradorite, augite, and titano-ferrite or magnetite, generally black or dark green. Olivine is frequently present. Basalt occurs in dykes or sheets.

Dolerite. A largely crystalline rock of the same composition as basalt. An intermediate stage is sometimes called 'anamesite.'

Leucite Rock. A crystalline-granular compound of leucite and augite, with magnetite, porphyritic or compact. (Mr. S. Allport has discovered this mineral in the Wolf Rock, off the coast of Cornwall.)

Hypersthene Rock. Crystalline granular compound of Labradorite and hypersthene with titano-

ferrite. Much of the doleritic lava of the north of Ireland is of this composition. Hypersthene is a variety of pyroxene rich in oxides of iron, and manganese. Generally hypersthene rock is associated with strata older than the Tertiary period.

(*Acidic.*)

TRACHYTE. Generally a light greyish rock composed of sanidine and other felspars, with accessory minerals such as mica (biotite), hornblende or augite.

(*a*) *Trachyte porphyry.* Felspathic base with crystals of sanidine, and grains of quartz. (Co. Antrim and Down, Ireland.)

RHYOLITE. A compact, enamel-like, or vitreous matrix, enclosing grains or crystals of sanidine and quartz.

PHONOLITE (or Clinkstone). A compact base, in its fresh state dark greenish grey, showing here and there single cleavage surfaces of vitreous felspar.

PITCHSTONE. A homogeneous vitreous mass, with conchoidal fracture, translucent at the edges, of various colours, of red, yellow, brown, green, to black.

(*a*) *Pitchstone porphyry.* A base of the above when enclosing crystals of glassy felspar, quartz, or mica.

II. FRAGMENTAL.

(*Of various Geological Ages.*)

FELSPATHIC ASH, or TUFF. A mass, generally

rudely stratified, composed of small fragments or dust of volcanic materials, along with which fragments of other rocks may also occur. These materials are generally more or less consolidated, and when bound together by carbonate of lime form a calcareous ash of tolerable hardness.

AGGLOMERATE. A mass, rudely stratified or amorphous, composed of large and small fragments of felspathic materials, which have been shot out of a volcanic vent during eruption. Sometimes large bombs are imbedded in ash and agglomerate, as is the case amongst the Lower Carboniferous rocks of Ayrshire.

GRENSTONE ASH, or TUFF (*Diabase-tuff*). Under this head are included the tuffs which are composed mainly of comminuted materials of some variety of trap-rock, probably diabase or melaphyre. They occur in Co. Limerick and Wexford. (Jukes.)

METAMORPHIC ROCKS.

GNEISS. A crystalline granular aggregate of quartz, felspar, and mica; texture foliated. (Gneiss often passes into foliated granite on the one hand, and into mica-schist, &c., on the other.)

(*a*) *Porphyritic-gneiss;* when containing large distinct crystals of felspar.

(*b*) *Syenitic-gneiss;* when hornblende is present as an essential.

(*c*) *Protogine-gneiss;* when chlorite or talc is present as an essential.

GRANULITE. An aggregate of felspar and quartz, fine grained, foliated or laminated; usually with some mica.

MICA-SCHIST. A foliated aggregate of mica and quartz, generally in alternate laminæ.

(*a*) *Quartz-schist;* when the proportion of mica is very small, and the quartz presents a foliated structure.

(*b*) *Chlorite-schist, Talc-schist, Epidote-schist;* when these minerals respectively prevail. (We may also have compounds, such as chloritic mica-schist, &c.)

HORNBLENDE-ROCK. A compact or crystalline granular rock, formed chiefly of hornblende, with felspar and accidental minerals; structure more or less amorphous.

(*a*) *Hornblende-schist;* the above when foliated.

QUARTZITE (Quartz-rock). A granular or compact mass of quartz, firmly bound together, splintery fracture. (Veins of white quartz are generally present in this and other metamorphic rocks.)

SERPENTINE. Hydrated silicate of magnesia; massive, or foliated, or fibrous; soft; colour varying from pale leek-green to dark olive-green, or reddish-brown, &c.; often associated with diallage rock.

DIALLAGE-ROCK. A variety of gabbro, composed of Labradorite or Saussurite and diallage; usually

with other minerals. (Diallage-rock is not always a metamorphic rock, though generally associated with rocks of this class.)

CRYSTALLINE LIMESTONE, and MARBLE. Limestone which has taken the crystalline structure owing to metamorphic action. It is often schistose and micaceous. (Connemara, Donegal, Apuan Alps in Italy.)

SEDIMENTARY ROCKS.

(*Mechanically formed.*)

CONGLOMERATE, or PUDDINGSTONE. A rock consisting of consolidated pebbles, more or less rounded, and imbedded in a basis of varying material; either calcareous, siliceous, or ferruginous. Quartzose sand often forms the binding material.

BRECCIA. When the component fragments, instead of being rounded, are angular. Some of the most beautiful marbles are breccias bound together by a calcareous paste. Breccias are generally more littoral in their mode of formation than conglomerates, and in some cases are referable to the agency of floating ice.

SANDSTONE, or GRITSTONE. Under this head is included siliceous freestone. Sandstones consist of small particles of silex and other materials bound together by various cementing substances, such as oxide of iron, silica, or calcareous matter. When flakes of mica occur—generally in the planes of bed-

ding—the stone is called a 'micaceous sandstone.' Amongst this class of rocks, the phenomena of oblique lamination and ripple marks are of frequent occurrence; and when the stone is of a light colour and suited for buildings of a higher class, it is termed a 'freestone.' The hard and coarser varieties, with a rough surface, are called grits; as, for example, the millstone grit of Yorkshire.

FLAGSTONE. Sandstones which split into thin and even layers along the planes of bedding, are called 'flagstones.' Generally this tendency to split is due to laminæ of mica deposited over the surfaces of successive strata.

CALCAREOUS ROCKS.

(*Organically formed; less frequently chemically formed.*)

LIMESTONE. A rock, in its pure state composed of carbonate of lime, but generally containing foreign ingredients, such as silica, alumina, carbonate of magnesia, carbonate of oxide of iron, and carbonaceous matter.

Limestones are of all colours; and all the great marine limestone formations may be referred, directly or indirectly, to the agency of marine animals. Tufaceous limestones, travertine, and 'Egyptian alabaster' have been formed by precipitation from waters charged with carbonate of lime.

Crystalline limestone. Some kinds of unaltered limestones, full of organic remains, are highly crystalline in structure, as sometimes is the case with the Carboniferous limestone of Derbyshire. In other cases, the crystalline structure is due to metamorphic action, as in that of the Carrara marble (see *ante*, p. 13).

Compact limestone. This rock is generally earthy, devoid of crystalline structure, and of dull blue, grey, black, or mottled colours. The limestones of the Lias are generally of this character.

Chalk. A white, fine-grained, generally soft limestone, often enclosing nodules or bands of flint, and on microscopic examination found to consist of shells of marine animals, such as *Foraminifera*, &c.

Oolite, and *oolitic freestone.* A limestone composed of innumerable little spheroidal concretions, firmly cemented by carbonate of lime or calc-spar. When the concretions are as large as a pea, it is called a 'pisolite,'—such as occurs at the base of the Inferior Oolite near Cheltenham. The oolitic limestones of the Jurassic system are generally fossiliferous, and of a light yellowish colour, producing an agreeable building material, and durable when not exposed to a smoky atmosphere. Oolite also occurs in the Carboniferous system, as on the shores of Killala Bay, in Co. Mayo.

Nummulite limestone. A great formation of white, yellow, or reddish-mottled limestone, formed princi-

pally by the agency of a genus of foraminifera called *Nummulites*. This rock has been used as a marble in Italy, though seldom occurring with a crystalline structure.

Hydraulic limestone. Limestone which has the property of setting under water after calcination. This is considered to be due to certain proportions of silica and alumina, and perhaps of carbonate of magnesia. These limestones are generally earthy, compact, and of a blue colour. They are derived from the Lias of England, the lower Carboniferous series of Scotland, and of Ballycastle, Co. Antrim, &c.

Dolomite, or Magnesian limestone. A limestone containing a large proportion of carbonate of magnesia; crystalline or granular; generally of a yellowish colour, and weathering into a brownish powder with a sandy appearance; sometimes fossiliferous, and containing various proportions of foreign matter. The dolomite of the north-east of England is one of the chief building stones of the country.

Gypsum, or *Alabaster.* White, yellow, red, or mottled, crystalline, or granular sulphate of lime; occurring in beds, or lenticular masses amongst the sedimentary rocks; often in connection with rock-salt.

CHAPTER II.

CLASSIFICATION OF BRITISH STRATA.

For the sake of those who may not be familiar with the order of succession of the geological formations into which the strata have been distributed, the following outline is here presented. For fuller details, which would here be out of place, the reader may consult Lyell's *Student's Manual of Geology*; Jukes' *Manual of Geology*, edited by Professor Geikie; or other books on the subject.

Those formations to which special reference is made in this work are printed in italics.

TABLE OF BRITISH SEDIMENTARY STRATA.

POST TERTIARY.

Pleistocene	Recent strata. Post Glacial strata. Glacial strata. Pre-Glacial strata.

CAINOZOIC, OR TERTIARY.

Pliocene		Crag of East of England.
Miocene		*Lignite and basalt of Antrim and Mull.*
Eocene . . .	Upper .	Hempstead Beds. Bembridge Beds. Osborne Beds.
	Middle .	Headen Beds. Bagshot Beds.
	Lower .	Beds of London and Paris Basins, also *Nummulite Limestone of South of Europe*, &c.

MESOZOIC, OR SECONDARY.

Cretaceous	Upper		*Chalk*, &c.
			Upper Greensand.
	Lower		Gault.
			Lower Greensand (UpperNeocomian).
		Wealden Group	Weald Clay.
			Hastings Sand, &c.
			Ashburnham Beds, &c.
Jurassic	Upper		*Purbeck Beds* (Limestone).
			Portland Stone.
			Portland Sand.
			Kimmeridge Clay.
	Middle		*Coralline Oolite.*
			Oxford Clay.
	Lower		Great Oolite.
			Fuller's Earth.
			Inferior Oolite.
	Liassic		Upper Lias.
			Middle Lias, or Marlstone.
			Lower Lias.
New Red Sandstone, or Trias	Keuper		*Rhætic or Penarth Beds.*
			Red Marl.
			Lower Keuper Sandstone.
			Dolomitic Conglomerate (Somerset)
	Bunter		*New Red Sandstone.*

PALÆOZOIC, OR PRIMARY.

Permian	Upper	*St. Bees' Sandstone*, &c.
	Middle	*Magnesian Limestone*, &c.
	Lower	*Lower Permian Sandstone*, or Marls and Breccias, &c.
Carboniferous	Upper	*Coal-measures.*
		Millstone Grit.
	Lower	*Yoredale Beds.*
		Carboniferous Limestone.
		Lower Limestone Shale (England).
		Calciferous Sandstone (Scotland).
		Lower Carboniferous Slate, Coombola Grits, &c. (Ireland.)

Devonian . . .	Upper Devonian (Devonshire) .	Upper Old Red Sandstone (Scotland).	
	Middle Devonian (Devonshire) .	Middle Old Red Sandstone (Scotland).	
	Lower Devonian (Devonshire) .	Lower Old Red Sandstone (Scotland).	
Silurian . . .	Upper .	Tilestones (passage Beds).	
		Ludlow Beds.	
		Wenlock Beds.	
		Upper Llandovery Beds.	
	Lower .	Lower Llandovery Beds.	
		Caradoc or Bala Beds.	
		Llandeilo Flags.	
		Tremadoc Slates.	
		Primordial Zone or Lingula Beds.	
Cambrian	Harlech Grits .	Grits, Quartzites, and Schists (Ireland) . .	Red Sandstone & Conglomerate (Scotland).
	Purple Slates .		
	Longmynd Rocks		
Laurentian . .	Fundamental Gneiss (N. W. Highlands).		
	Grits and Quartzites (St. David's Head).		
	Laurentian Gneiss, Schists, and Serpentines (Canada).		

PART II.

GRANITIC ROCKS.

CHAPTER I.

GRANITE.

Granit (*Germ.*) Granite (*Fr.*) Granito (*Ital.*) Sp. gr. 2.6–2.9.

THE origin of the name 'granite' is involved in obscurity. It is stated by Scipio Breislack to have been used by Cæsalpinus as far back as the year 1596, and was found by Emmerling in a work by Pitton de Tournefort, written in 1698;[1] and while it was subsequently employed to designate rocks of a coarsely granular character, it is probable that Werner and Hutton gave more precision to its use. On the other hand, Chateau traces the name to the Italian 'granito,' from the grains being of different colours.[2] But whatever its derivation, the name is now understood amongst petrologists to designate a rock of a crystalline-granular texture—of igneous or metamorphic origin—and composed of, at least, three constituents, quartz, felspar, and mica.

[1] Zirkel, Petrographie, i. 475.
[2] Technologie du Bâtiment.

Granite is an acidic (or highly silicated) rock, the proportion of silica varying from 65-81.7 per cent.[1] The different minerals of which it is formed may generally be distinguished by the eye, and are so arranged, that the felspar and flakes of mica are imbedded in the free silica (or quartz); owing to this condition of the minerals, it has been inferred by Senft that the silica which was the most difficult to fuse was the last to solidify, and retained a certain degree of viscosity after the other minerals had assumed the crystalline form.[2] Where the silica has been in excess, it appears to have been injected into the veins which are often found traversing granitic rocks; on the other hand, Dr. Sterry Hunt considers that such veins, even when containing large crystals of orthoclase, may have been deposited from aqueous solution.[3]

From microscopic examination by Mr. Sorby,[4] and more recently by Dr. F. Zirkel, it has been ascertained that the quartz of granite contains minute cells partially filled with water, and these observers have inferred the presence of steam under great

[1] In rare cases, however, the proportion is lower; the Rev. Dr. Haughton finds one of the Galway granites to contain only 55.20 per cent. of silica. Quart. Journ. Geol. Soc. xvii.

[2] See Lyell, Elem. Geol. p. 538 (1871).

[3] 'On Granite Veins,' American Journal of Science, 1870.

[4] 'On the Microscop. Structure of Crystals, &c.,' Journ. Geol. Soc. Lond. vol. xiv. p. 453.

pressure, and a high temperature during the process of formation.[1]

Varieties of Composition. From the primary composition of granite already described, there are frequently considerable variations. Many varieties have two kinds of felspar, such as that of Egypt, which contains orthoclase and oligoclase; or that of Mourne, which contains orthoclase and albite; others again have two varieties of mica. Accidental minerals are sometimes present, generally in druses, such as tourmaline or schorl, beryl, chlorite or talc, while hornblende often appears and sometimes replaces the mica, in which case the rock becomes a syenite. When large and distinct crystals of orthoclase felspar are individually developed, the rock assumes a porphyritic structure, which adds much to its value and beauty for ornamental purposes. In this case, the orthose crystals often occur as twins, reflecting the light differently from their facets, and thus are capable of easy determination by the eye. These crystals frequently have a rich pink or flesh-colour, as

[1] Mr. Sorby has even gone further than this, and has shown from calculations founded on the extent to which the cavities are now filled with fluid, that certain conclusions may be arrived at regarding the relative depths at which granite has been formed in different localities. Thus he finds that the granites of the Highlands of Scotland indicate a pressure of 26,000 feet of superincumbent rocks more than those of Cornwall; the elvans (or granitic dykes) of the Highlands, one of 28,700 feet more than those of Cornwall; but these pressures depend on the temperatures of consolidation.

in the case of the porphyritic granites of Galway, Shap Fell, and Syene in Egypt.

But perhaps the most generally admired of the varieties of granite are those which, like the Peterhead stone, are of a rich pink colour, arising from the predominance of rose-coloured felspar. There are indeed few rocks in this country which are superior to such in richness of colour, and suitability for ornamental purposes, especially when they are capable of being extracted in blocks of large size, and of receiving a high polish.

Foliated Granite, or *Gneiss.* The minerals of which granite is composed are sometimes arranged in parallel layers or leaves, in which case the rock is said to be 'foliated,' and passes into gneiss. This structure is often observable over large tracts of country, as in Donegal and Galway, and is usually characteristic of those masses which have been formed by a process of metamorphism. The structure also is sometimes only apparent when the rock is viewed in its natural position, and often is persistent as regards general direction over large tracts of country.

Graphic Granite. This variety seems to occur almost exclusively in veins, particularly those which traverse gneiss.[1] It contains but little mica; and the peculiarity of the structure to which it owes its name is due to the arrangement of the quartz and

[1] McCulloch's Geol. Classification of Rocks, p. 235 (1821).

felspar of which it is composed in long parallel prisms, which are sometimes triangular, in other cases hexagonal and flattened. The prismatic structure is seen, therefore, in only one direction, and the letter-like arrangement in another, or transversely to the axes of the prisms.

Geological Age. Although it was once supposed that granite is the oldest of rocks, it is now known, from observations extending over large tracts of the earth's surface, that granites have been formed at several geological periods from the Silurian down to, at least, the close of the Cretaceous period. Thus it is known that the granite of Cornwall and Devon is more recent than the Carboniferous period; that the granite of the Alps of Savoy is more recent than the Jurassic period; and that the granite of the Eastern Pyrenees is more recent than the White Chalk. On the other hand, there are granitic rocks of great antiquity, such as some of those found in Scandinavia, the Highlands of Scotland, Donegal, and Galway, all of which are older than the Devonian; some, than the Upper Silurian periods.

Mode of Occurrence. From the massive and homogeneous character of granite, it is eminently capable of yielding large blocks suitable for structures which are intended to withstand the assaults of time, the violence of the waves of the sea, or the crushing effects of enormous pressure. It is, therefore, used for the

construction of breakwaters and harbours, lighthouses, docks, fortifications, foundations, and voussoirs of bridges. On the other hand, it is unsuited for fine sculpturing on account of its crystalline-granular structure and coarseness; so that when we require a material suited for the ornamental portions of an ecclesiastical or public edifice, we are obliged to have recourse to the less granular and softer materials which are to be found amongst the formations of limestone, sandstone, or dolomite.

Mode of Formation. The igneous origin of granite was first demonstrated by the philosopher Hutton from actual observation,[1] and maintained by him against his rival Werner and his school during the celebrated controversy of 'the Neptunists' and 'the Vulcanists.' But while nearly all physical geologists are agreed that granite has resulted from a state of igneous fusion in presence of vapour of water, and under a high degree of pressure, it has been demonstrated by Professor Haughton, that there are two great classes under which probably all granites may be arranged, namely, metamorphic and eruptive.[2]

[1] Playfair's Illustrations of the Huttonian Theory. Hutton, convinced in his own mind, from the crystalline structure of granite, that it had been formed by cooling from a state of igneous fusion, went in search of an illustration of his views amongst the mountains of Scotland; and in Glen Tilt, to his great delight, discovered veins of granite traversing schistose rocks.

[2] Journ. Geol. Soc. Lond. vols. xii. and xviii.

The same observer also shows that there are certain specialities of structure and composition attached to each of these classes. Thus, under the metamorphic series, he groups the granites of Scandinavia, of the Scottish Highlands (in part), of Donegal, Galway, and Newry; and under the eruptive series he places the granites of Wicklow, the Mourne mountains, and Dartmoor.

Unquestionably this is a classification which will hold good in a general way; and several special districts, such as Galway and Down in Ireland, afford examples of each of these classes of granite in close proximity. At the same time, it is somewhat difficult to define very clearly what we mean by 'metamorphic' as distinguished from 'eruptive' origin; for, as we may assume that sedimentary rocks, such as grits and slates or shales, when fused by heat under great pressure of superincumbent strata will sometimes result in the production of granite, it is clear that all granites may be originally in some sense metamorphic rocks.

The distinction, however, refers not to the original state and origin of a granitic mass, but to its position in relation to the stratified rocks by which it is bounded or enclosed. If, as in the case of the foliated granite of Galway, it is found to occur merely as a portion of the general mass of sedimentary rocks in which the metamorphic action has been carried out

to a greater or less extent, it may be regarded as metamorphic; if, on the other hand, after it has been elaborated by fusion or metamorphic action at a certain depth in the interior of the earth's crust, it has been irrupted amongst strata occupying a higher zone, and not connected with those out of which it has been formed, it may then be regarded as irruptive. In the former case we have a process of assimilation of stratified materials into the mass of crystalline rock; in the latter, of assimilation followed by intrusion amongst higher strata, the result of internal forces.

Chemical Composition. Many analyses of granite have been made, of which I here quote thirteen examples,[1] from which it will be observed that the predominating constituent is silica, and the next in importance alumina. The relative proportions of potash and soda are also features of importance, because in the soda granites the orthoclase is replaced or accompanied by albite, as in the case of the granite of the Mourne mountains in Downshire.

[1] Chiefly taken from Dr. F. Zirkel's Lehrbuch der Petrographie, vol. i. 1866. Zirkel states that the granite of the Devil's Wall (Teufelsmauer) near Krems contains as much as 81.77 per cent. of silica; and that of Goragh Wood, near Newry, only 62.08; this latter analysis having been determined by the Rev. Dr. Haughton, F.R.S.

Chemical Analyses of Granites.

	I.	II.	III.	IV.	V.	VI.	VII.
Silica	73.13	72.11	69.31	70.72	73.00	73.20	72.24
Alumina	12.49	15.60	16.40	14.16	13.64	15.48	14.92
Oxides of Iron	2.58	1.53	4.30	3.22	2.44	1.72	1.86
Oxides of Manganese	0.57	0.26	0.03	—	—	—	0.32
Lime	2.40	1.26	3.06	1.03	1.84	0.96	1.68
Magnesia	0.27	0.34	0.83	0.66	0.11	—	0.36
Potash	4.13	5.00	2.87	5.37	4.21	4.80	5.10
Soda	2.61	2.27	3.29	2.54	3.53	3.18	3.51
Water	0.53	0.83	0.84	—	—	—	—
Loss	—	—	—	1.10	1.20	—	—
	98.71	99.20	100.93	98.80	99.97	99.34	99.99

	VIII.	IX.	X.	XI.	XII.	XIII.
Silica	74.82	70.09	66.81	75.00	71.41	70.25
Alumina	16.14	15.44	19.05	13.24	14.45	16.00
Oxides of Iron	1.52	6.13	5.02	2.52	2.58	2.50
Oxides of Manganese	—	trace	—	—	—	
Lime	1.68	1.20	3.26	0.69	2.49	1.16
Magnesia	0.47	trace	0.31	—	1.11	9.00
Potash	3.55	4.19	2.78	4.33	2.77	
Soda	6.12	3.27	2.85	3.07	3.05	
Water	—	—	1.30	0.80	1.25	0.65
	104.30	101.38	101.38	99.65	99.11	100.00

I. Large-grained granite, of white orthoclase, greyish white quartz, a little oligoclase, and black mica, from Streitberg in Silesia. Streng, Poggend. Ann. 1852, 122.

II. Fine-grained granite of Heidelberg, with much quartz, without oligoclase and with magnesia-mica (Biotite). Streng, *supra cit.* 130.

III. Granite from Meerauge im Fischseethal (Carpathians); coarse-grained, with much oligoclase and orthoclase, little quartz, much green biotite, a little white mica. Streng, *supra cit.* 125.

IV. Fine-grained, from Monte Mulatto in the Tyrol; consists of quartz, orthoclase, and tourmaline instead of mica. Kjerulf, 1855.

V. Large-grained granite, with much quartz, from Fox Rock near Dublin. Haughton, Quart. Journ. Geol. Soc. Lond. vol. xii. 1856.

VI. Medium-grained granite, from Blackstairs Mountain, Co. Wexford. Haughton, *supra cit.* Contains no oligoclase.

VII. Medium-grained granite, from Doocharry Bridge, Co. Donegal; consisting of flesh-coloured orthoclase, grey oligoclase, quartz, and a little black mica. Haughton, *ibid.* vol. xviii. p. 402 (1863).

VIII. Granite from Baveno, Italy; containing flesh-coloured orthoclase, white oligoclase, quartz, and dark green mica. Bunsen, Mittheilung an Roth, Gesteinsanalysen, 1862.

IX. Granitite from Warmbrunn in Silesia; red orthoclase, yellowish oligoclase, quartz, and a little biotite. *Ibid.*

X. Granite from Meineckenberg in the Harz; prevalent bright greenish oligoclase, a little orthoclase, much mica and little quartz. Fuchs, N. Jahrb. für Mineralogie, &c., 1862.

XI. Granite from the Mourne Mountains; containing quartz, orthoclase, albite, and green mica. Haughton, Quart. Journ. Geol. Soc. vol. xii. 192.

XII. Protogine granite, from the northern flank of Mont Blanc. Schönfeld and Roscoe, quoted by Zirkel, Petrographie, vol. i. 492.

XIII. Egyptian granite (or 'syenite'), from a fragment of an antique in the collection of the Louvre, Paris, by Professor Delesse. Journ. Geol. Soc. Lond. vol. vii. 7.

Varieties of Granite and Examples. The varieties caused by variations in the number and proportions of the constituents, their colours, and the presence of accidental minerals, are almost endless; but I shall select a few of the most remarkable and more useful examples for description. In some cases, as in the Western Alps, talc replaces the mica, in which case the rock receives the name of 'protogine' granite;[1]

[1] Some doubt has been thrown, on the authority of Dr. Haughton, on the accuracy of this generally received view. See Jukes' Manual of Geology, 3rd edit. 124 (1872).

in others, schorl or tourmaline appears and produces 'schorlaceous' granite as at Killiney Hill near Dublin, and several localities in Cornwall; in others, hornblende replaces or accompanies the mica, and we have 'syenite' and 'syenitic' granite; and lastly, when the orthoclase crystals assume an angular arrangement with reference to the quartz, or the quartz with reference to the felspar, so that they present the appearance of oriental characters, we have the variety known as 'graphic granite,' examples of which occur in the Schloitzbachthal, near Tharand in Saxony,[1] and at Clifden in Connemara, Ireland.[2]

Specialities of Granite. The specific gravity of ordinary granite being 2.66, a cubic foot weighs 166.2 lbs., and a cubic yard as nearly as possible two tons; just about twice the weight of a cubic yard of coal.

Granite, according to Professor Ansted, generally contains about 0.8 per cent. of water, and is still capable of absorbing about one-fourth more, or 0.2 per cent. In other words, a cubic yard of two tons contains in its ordinary state about 3.5 gallons of water, and some specimens can absorb nearly a gallon more, on being placed in pure water for a short period. It is important, in selecting specimens of this rock

[1] Rocks Classified, by B. von Cotta (Lawrence's Trans.), p. 206.
[2] Observed by the Officers of the Geological Survey.

for structural purposes, to observe the quantity of water they are capable of absorbing, as the influence of frost on stone is in proportion to the quantity of water it takes up, and the result determines to some extent its durability.

The power of granite to resist crushing forces varies much with the character of the rock. The valuable series of experiments made by Mr. Wilkinson on the granites of Ireland, show considerable variations even amongst selected specimens. Cubes of one-inch sides having been tested by means of a lever, specially prepared by Mr. Mallet, C.E., it was found that the weight in lbs. required to crush the specimens varied from 2310 up to 13,400, the maximum being obtained from a specimen from Newry, County Down; the minimum from Ballyknockan. The granites from Killiney and Kingstown afforded good results.[1]

[1] Prac. Geol. and Arch. of Ireland, by G. Wilkinson, M.R.I.A. (1845.)

CHAPTER II.

GRANITES OF SCOTLAND.

Peterhead, Aberdeenshire. The red granite of Peterhead, quarried at Stirling Hill, is justly prized for the beauty of its colour, its closeness of texture, and the large blocks which it yields from the quarry. It is extensively employed for columns, tesselated pavements, and ornamental work both within and outside of buildings; and fine examples may be observed in the pillars of Carlton Club House, the Fishmongers' Hall, in London; the columns for the interior of St. George's Hall, Liverpool; and those of the Provincial Bank of Ireland, in Dublin. The large pedestal and tazza formed out of this granite in the hall of the Museum of Practical Geology, London, is also a most successful example, both of skilful workmanship and excellence of material.[1] The granite of Peterhead is composed of red orthoclase, albite, black mica, and quartz, and is considered by Dr. Haughton to be of eruptive origin.[2] It weighs 165 lbs. 14 ozs. per cubic foot.

[1] This large tazza (or vase) was made by Messrs. Macdonald and Leslie, Aberdeen.

[2] Proc. Roy. Soc. vol. xviii. (1870). A specimen of this granite, showing the two felspars, orthoclase and albite, is in the Museum of Trinity College, Dublin.

A finely crystalline light red granite is obtained at Cornegie, also in the county of Aberdeen.

Aberdeen. This rock has been very extensively employed for building and ornamental purposes over the United Kingdom, as well as in America and the Continent; as it can be extracted in large blocks, and takes a fine polish. It has a prevailing greyish tint, and, according to Haughton,[1] is of metamorphic origin, and probably much more ancient than the red granite of Peterhead. It is a compound of quartz, orthoclase, oligoclase, and black and white mica; resembling in composition, though not in colour, the granites of Donegal and Norway. Out of this stone the city of Aberdeen, perhaps the cleanest and freshest-looking city in the British Islands, is built; and might be referred to by Mr. Ruskin to illustrate his views of the purifying influences of granitic rocks on the inhabitants of countries where they prevail.[2] The principal quarries are at Dancing-Cairn, Rubislaw, and Tyrebagger.

Kirkcudbrightshire. This granite is largely quarried at Craignair and Creetown, and has been used in the construction of the Liverpool Docks; the Birkenhead, Newport, and Swansea Docks; the Liverpool Borough Bank, Branch Bank of England, and other buildings, both of that town and of Man-

[1] Proc. Roy. Soc. vol. xviii. (1870).

[2] Modern Painters, iv. pt. v. ch. 8.

chester.[1] It is of a greyish colour, and generally porphyritic.

Strontian, Argyleshire. Medium-grained grey granite, consisting of quartz, oligoclase white felspar, and black mica in abundance.[2]

Island of Arran. The central group of mountains of this remarkable island, rising at Goat Fell to an elevation of 2875 feet, is composed principally of granite of two varieties, the coarse-grained and the fine-grained, formed probably at successive periods. In composition, however, they are similar, being formed of white orthoclase, a triclinic felspar probably oligoclase, quartz, and a little black mica; the quartz is very abundant.[3]

Isle of Mull, &c. This island produces fine pink and red granites, which are now largely worked by the Scottish Granite Company. From the Ross of Mull it was proposed to obtain a monolith, to be erected in honour of the late Prince Consort, in Hyde Park.[4] The rock consists of pink orthoclase, a little mica, and much silica. Granite is also obtained from Portsoy, in Banffshire; Dalmore, Sutherland; Oban, in Argyleshire; High Rock, Breadalbane, Perthshire; and Tiree, in the Hebrides.

[1] Mr. R. Hunt, Mineral Statistics, part ii. 1858, p. 273.

[2] Brit. Assoc. Rep. 1863, p. 62.

[3] This determination of the composition of the Arran granite has been kindly communicated to me by Mr. S. Allport, F.G.S.

[4] Descrip. Guide to the Museum of Prac. Geol. p. 18 (1867).

CHAPTER III.

GRANITES OF ENGLAND.

The occurrence of granite in England is limited to a very few localities, viz.:—Shap Fell, in Cumberland; Anglesea, Devon and Cornwall, Lundy Island, the Channel Islands, and the Isle of Man. Of these the following are selected for description:—

Granite of Dartmoor. Granite forms at Dartmoor an elevated tract of moorland, rising into fantastic masses, or Tors, resulting from the process of weathering along the original joints of the rock. It has a prevailing greyish colour, and is frequently porphyritic; in which form it has been used in the construction of London Bridge.

Quarries were formerly opened at High Tor, on the east of Dartmoor, and at Hingston Down; but those at the former locality are now abandoned, and others at Cheesewring, near Liskeard, have been opened, from which a stone of a beautiful quality is raised, and exported in large quantities from Looe.[1] There are also quarries at Fremator, near Tavistock, and at Blackenstone, Dartmoor.

Granites of Cornwall. The granites of Cornwall

[1] Descrip. Guide M. P. G., p. 19.

are extremely variable in quality, structure, and composition, being sometimes so soft as to produce kaolin, or porcelain clay; sometimes hard and durable; again, they are frequently schorlaceous and porphyritic, as at Land's End.[1] In composition, there are also varieties containing two felspars, pink and white; or two micas, grey and black.[2] The principal quarries are those near Liskeard (already referred to), those of Lamorna, west of Penzance; Penryn, near Falmouth; and Mill Hill, in Maldron. The stone from these quarries is of excellent quality.

The granites of Devon and Cornwall have been shown by Sir H. De la Beche to be of an age intermediate between the Lower Carboniferous and Triassic periods.[3]

The following are some of the principal works which have been constructed in part, or altogether, of Cornish granite: The Portland breakwater, from Penryn and Lamorna quarries; the Keynham Docks; the Commercial Docks, London; the Birkenhead Docks; the National Works at Chatham and Portsmouth, from the same localities; the Wellington monument at Strathfieldsaye, the shaft of the column being of one solid block thirty feet in height, from Constantine.

[1] See a good representation of this porphyritic granite in Lyell's Student's Manual of Geology, p. 540.

[2] A fine collection of varieties of granite from the neighbourhood of Penzance is to be seen in the Mus. of Trinity College, Dublin.

[3] Geological Observer, p. 563.

The Cheesewring granite has been used in the London Docks, Westminster Bridge, the Thames Embankment, Rochester Bridge, the Docks at Copenhagen, the Great Basses lighthouse near the Island of Ceylon, and the tomb of the Duke of Wellington in the crypt of St. Paul's. Waterloo Bridge is built of Cornish granite; and London Bridge of a porphyritic granite from Devonshire.[1]

The Channel Islands. Large quantities of granite have been raised and exported from the quarries of Mount Mado and La Perruque in Jersey, as well as from Guernsey and the little island of Herm.

Mount Sorel, Leicestershire. The syenitic-granite of Mount Sorel is highly esteemed in London and elsewhere, on account of its warm rose-tint—which renders it suitable for ornamental purposes—and as a contrast to the light grey or brown colours of the ordinary building stones. It is, however, extremely

[1] *Kaolin,* or *Porcelain Clay.* This substance as used in England is chiefly derived from the decomposed granites of Cornwall and Devon, as well as at Fetlar, one of the Shetland Islands (Bristow's Glossary of Mineralogy, 1861). Large quantities of this material are sent to Worcester and the Staffordshire Potteries, where, along with flints from the Chalk, and chert from the Carboniferous limestone of Derbyshire, it is ground under water into a fine mud, perfectly white, which is manipulated into various porcelain wares which vie with those of Dresden and Sèvres in beauty of design and excellence of execution. The decomposition of the felspar in the granite is probably due to the percolation of water holding carbonic acid in solution.

hard, and consequently expensive; but is capable of being extracted from the quarry of any required dimensions, and may be moulded to any desired form. It is also well suited for paving.

Lundy Island, Entrance to Bristol Channel. This granite has been worked to some extent, but not largely. It is a quaternary compound of quartz, white felspar, and black and silvery white mica, the latter comparatively rare. It is traversed by elvan dykes.[1]

Shap, Cumberland. The granite of Shap is a very handsome porphyritic stone, forming a portion of Wasdale Crag, near Penrith. It is somewhat variable in texture; but the general appearance is that of a rich reddish-brown crystalline granular base, composed of reddish orthoclase, yellowish oligoclase, quartz, and black mica, in which large flesh-coloured orthoclase crystals are abundantly distributed, sometimes as twins.[2] The stone takes a fine polish, and is now systematically worked by a company, who have set up machinery for cutting and polishing by the side of the Lancaster and Carlisle Railway, near Shap Station.

Immense numbers of boulders of Shap granite are dispersed over the country east of the Fell.

[1] Sir H. F. De la Beche, 'Rep. Devon and Cornwall,' p. 186.
[2] Dr. Nicholson and Prof. Harkness, Geol. of the Lake District.

CHAPTER IV.

GRANITES OF IRELAND.

Granite is developed in four districts of Ireland: 1. Donegal, on the north-west; 2. Galway and Mayo, on the west; 3. Wicklow and Wexford, on the south-east; and 4. Down and Armagh, on the north-east.

1. *Donegal.* The granite of this region is associated with the great tract of metamorphic rocks which range from Donegal Bay on the south-west to Glengad and Inishowen Head on the north-east, and reappear amongst the Highlands of Scotland. The principal mass of the granite coincides very nearly with the axis of the Gweebarra and Glenveagh valleys; but from the head of Gweebarra the granite spreads out westward, and forms the whole of the coast-line from Bloody Foreland to the mouth of Gweebarra River.

From the admirable Report[1] presented to the British Association by Mr. R. H. Scott, Sir R. Griffith,

[1] 'On the Constitution of the Granites of Donegal,' Brit. Assoc. Rep. 1863, p. 51, *et seq.*; also Haughton, 'On the Granites of Donegal,' Journ. Geol. Soc. Lond. vol. xviii. 402.

and the Rev. Dr. Haughton, it appears that the main mass of the granite is of a reddish colour, and may be regarded as a quaternary, and sometimes a quinary, aggregate of red orthoclase, oligoclase, quartz, black mica, and sometimes white mica; and that hornblende, sphene, schorl, beryl, and garnets are occasionally to be recognised. This granite presents a bedded aspect, while at the same time it has been observed to branch off into dykes traversing the surrounding metamorphic strata of schist and crystalline limestone.

There is also another 'white granite' with sphene and black mica occurring at Kindrum in Fanad, and in Arranmore Island. It is coarsely crystalline. In this island also there is a largely crystalline red granite which takes a fine polish, and is capable of being extracted in large blocks; one of these measuring 90 × 20 feet, having been found on the shore at the south-east corner of the island. The granite rocks of Donegal are unquestionably capable of yielding a very handsome ornamental stone.

The analysis of the granite from Doochary Bridge by Dr. Haughton has already been given (p. 29).[1] It has a rose-tint, is moderately fine-grained, and consists of large-sized pink orthoclase, a little green-

[1] In the Museum of Trinity College, Dublin, are fine specimens of beryl in Donegal granite; also specimens of granite from Garvary Wood, Doocharry Bridge, and Dunglow. Haughton, Brit. Assoc. Rep. 1863, p. 58.

ish oligoclase in crystals of smaller size, quartz, and black mica.[1]

The granite of Garvary Wood is also a handsome stone, and consists of large pink orthoclase crystals, oligoclase, quartz, and black mica.

2. *Galway*. The granitic district of Galway extends over a large and wild tract from the town of that name to Roundstone Bay. It contains at least two principal varieties, which, according to the observation of the officers of the Geological Survey, may be arranged under the heads of metamorphic and intrusive.[2] These granites are associated with metamorphic strata, probably of lower Silurian or (still more ancient) date, together with quartz-porphyries, felstones, dioritic, and diabasic rocks, of intrusive origin. The former of these is a very handsome porphyritic rock, in which large crystals of red orthoclase are imbedded in a base composed of quartz, orthoclase, greenish oligoclase, and mica. This forms the characteristic Galway granite. It has been quarried at Furbogh, eight miles from Galway, and takes a fine polish. The latter, or 'Oughterard granite,' is composed of quartz, orthoclase, white and black mica, with iron pyrites as an accessory.

[1] 'On the Granites of Donegal,' Brit. Assoc. Rep. 1863, p. 61.

[2] Mr. G. H. Kinahan, Explanatory Memoir to accompany Sheets 104 and 113 of the Geol. Survey Maps: The intrusive granite occurs in mass near Oughterard, and is very quartziferous; the metamorphic is porphyritic and foliated. (p. 15.)

Little has been done in the way of utilizing these rocks, though there can be no doubt that the porphyritic granite is capable of yielding a stone of great beauty, and is well adapted for architectural purposes. A polished pillar of a porphyritic variety of granite may be seen in the Museum of the Royal College of Science, Dublin.

Another mass of intrusive granite occurs at Aillemore, to the south of Louisburg, consisting of orthoclase, oligoclase, quartz, and mica. It has not as yet been turned to any useful purpose.

3. *Wicklow and Wexford.* This granite forms a tract of mountainous country, extending in a S.S.W. direction from Blackrock near Dublin to Pollmounty near New Ross, and rising in Lugnaquilla to an elevation of 3039 feet, where it is capped by schist.

It is composed generally of quartz, orthoclase, and silvery grey mica, but occasionally contains black mica, tourmaline, killinite, fluor spar, and albite;[1] the prevalent colour of the rock is light grey; it has a mean specific gravity of 2.634, its general chemical composition may be judged of by analysis V. (page 28) of specimens from Fox Rock by Professor Haughton.[2] The granite of this district is capable of yielding

[1] First observed by Mr. Westropp in the granite of Dalkey. Journ. Geol. Soc. Dub. vol. ii. new ser. 213.

[2] Quart. Journ. Geol. Soc. vol. xii. p. 177, and vol. xiv. p. 300. Also Address to Dublin Geol. Soc. 1862.

stone of large dimensions and superior quality. From Killiney Hill enormous quantities have been extracted for the construction of the fine harbour and pier of Kingstown, the Thames Embankment, and O'Connell's Monument in Glasnevin, besides numerous structures in and around the Irish metropolis. Care in selection is, however, absolutely necessary, as there is considerable variation in the texture and durability of the stone. Dr. Haughton informs me that the old buildings of Trinity College were constructed with granite of inferior quality from Three Rock Mountain, while there is a beautiful fine-grained bluish granite which works kindly, from Blessington, and which has been employed with good effect in the new campanile which adorns the central quadrangle of the University. The granite of Glencullen and Kilgobbin, Co. Dublin, and Ballyknockan, Co. Wicklow, being less siliceous and more uniform in texture than that of Killiney, has been more generally employed in buildings in the city of Dublin, such as the Law Courts, the Wellington Monument in the Phœnix Park, erected by public subscription in 1829, and Nelson's Pillar in Sackville Street,[1] A cubic foot of Dalkey granite weighs 169 lbs. 9 ozs.

[1] A most valuable series of experiments on the crushing weight and other qualities of the Irish granites has been published by Mr. G. Wilkinson, M.R.I.A., in his work on Practical Geology and Ancient Architecture of Ireland, 1845.

The Killiney granite in one or two places is distinctly foliated.[1]

4. The granites of the north-east of Ireland lie in three distinct tracts of considerable extent, forming the mountain ranges of Mourne, which attains in Slieve Donard an elevation of 2975 feet; of Carlingford, and of Slieve Croob.

The granite of Mourne has been already partially described.[2] It forms a group of exceedingly picturesque hills, generally of conical outline, with occasional scarped cliffs and deep ravines. It is truly irruptive, and seems to have been intruded amongst the stratified rocks in a state bordering on solidity; and with a temperature only sufficient to indurate, but not to metamorphose, the Silurian rocks by which it is surrounded, and, in some places, surmounted.

The granite of Mourne has hitherto been used only to a very limited extent for building; and, owing to the numerous cavities it contains, and its distinctively crystalline structure, it is probably not as well adapted to architectural purposes as the granite from the Newry district adjoining.

Newry and Slieve Croob. This granite is altogether different in texture and composition from that

[1] A representation of the foliated granite is given by Mr. Du Noyer in the Explanation of Sheets 102 and 112 of the Geological Survey, p. 33.

[2] First described by Dr. J. E. Berger in the Trans. Geol. Soc. Lond., first ser. vol. iii.

of Mourne.[1] It is a potash granite, consisting of quartz, orthoclase, and black mica. The analysis of this granite from Goragh Wood Station shows an unusually low percentage of silica.[2] The rock is finely granular, uniform in texture, is capable of being delicately wrought, and produces a stone well adapted for building and decorative purposes. From a quarry near Castlewellan, large blocks were extracted and sent to London for the base and pedestal of the Albert memorial in Hyde Park, the stone having, I understand, been selected from amongst several others by the Queen herself.

Carlingford. The granite of Carlingford mountain is separated from that of Mourne by Carlingford Bay, and from that of Newry by a narrow band of Silurian rock. It is partly a syenite, or is associated with that rock, as also with diorites; and as regards its geological age, both Griffith[3] and Haughton[4] concur in regarding it as newer than the Carboniferous, as it is seen to penetrate the Carboniferous limestone in dykes at Grange Irish. North of Dundalk, it has decomposed into sand, and is penetrated by numerous dolerite dykes.[5]

[1] The granite of Slieve Croob and Newry is metamorphic, and is much older than that of Mourne and Carlingford.

[2] Haughton, *supra cit.* See also Zirkel, Petrog. vol. i. p. 486.

[3] Journ. Geol. Soc. Dublin, vol. ii. 113.

[4] Quart. Journ. Geol. Soc. vol. xii. 193.

[5] A specimen of the syenite from Carlingford Mountain is placed in the Museum of Trinity College, Dublin.

Belleek. The justly admired porcelain ware of Belleek, Co. Fermanagh, is obtained from an orthoclase granite in the vicinity of the factory which is situated at the spot where the waters of Lough Erne precipitate themselves along a series of cascades into the river of the same name. In general, porcelain is made from granitic rocks in a decomposed state, known as kaolin; but in this case the red orthose felspar retains its crystalline form in its original perfection, and on being calcined loses colour and becomes white. The metallic iron which separates itself from the rock during the process of calcination is afterwards extracted by simply immersing magnets into the powdered china clay when mixed with water; the particles of iron then adhere to the magnets, and are lifted out. It is probably this rock which is described by Mr. R. H. Scott, Sir R. Griffith, and the Rev. Dr. Haughton, as occurring in veins penetrating gneiss and schist.[1]

Arranmore Island. Porphyritic granite, consisting of quartz, reddish felspar, and black mica. In this granite the felspar predominates.

Tory Island. Coarse granite, almost entirely composed of quartz and felspar, a little mica, green or white.[2]

[1] Brit. Assoc. Rep. 1863, 'On the Granites of Donegal,' p. 54.
[2] Brit. Assoc. Rep. 1863.

CHAPTER V.

CONTINENTAL GRANITES.

France. Granite is largely distributed over the central parts of France, as well as Normandy and Brittany. It forms the plateau from which rise the giant volcanic cones of Auvergne,[1] and in Normandy is largely employed as a building stone both for churches and secular structures, which, receiving their characteristic features from the rock itself, are for the most part massive, severe, and devoid of elaborate ornamentation.[2]

A handsome porphyritic variety comes from Laber, in Brittany, consisting of grey and white felspar, quartz, and black mica, with large crystals of light pink orthoclase. A tazza formed of this stone is in the collection of the Royal College of Science, Dublin. A red granite which takes a good polish is obtained from Avallon, near Auxerre, Department of Yonne.[3]

Italy. The most important granite quarries in Italy are those of Fariolo, near Baveno, situated on the western bank of Lago Maggiore; of this rock the com-

[1] Scrope's Volcanoes of Central France, second edit. p. 37.

[2] Chateau, Technologie du Bâtiment,' i. 147.

[3] *Ibid.* p. 237.

position has already been given (p. 28.) It has a warm pinkish tinge, is fine grained, takes a good polish, and can be quarried in huge blocks, up to forty metres in length. It has been largely employed in the buildings of the cities of Milan, Florence, and Turin; and columns for the restored Basilica S. Paolo fuori le Mura at Rome of 10.40 metres in length have recently been extracted. In the interior of Milan Cathedral, on either side of the main porch, are two huge monolith columns of polished Baveno granite;[1] and of the same material are the columns which support the dome of the church of S. Carlo, Borromeo, which is built after the style of the Pantheon at Rome.[2]

The granites of the islands of Sardinia and Elba have been occasionally employed in some parts of Italy, especially along the western shores. The massive columns, eight in number, which support the dome of the Baptistry of Pisa (built A.D. 1278) are of granite from Elba. It is of a grey or slightly pink colour, consisting of white felspar, quartz, and black mica.

[1] These columns show traces of bands of foliation, which I have elsewhere observed in the granite of Baveno, and leads me to infer that it is a metamorphic rock. There is also a greyish granite from the same neighbourhood, consisting of quartz, white felspar, and mica; this may be irruptive. Fine crystals of orthoclase can be obtained from Baveno.

[2] For interesting details regarding the formation of minerals in this granite, see M. Fournet, Géologie Lyonnaise.

Other Continental Countries. It would be beyond the scope of this work to attempt to give an account in any detail of the distribution and characteristics of granite as it occurs over Europe.[1] I shall therefore only refer to a few localities of special interest. Granite forms a portion of the higher altitudes of the Pyrenees, the Western Alps, and the Carpathians. In Mont Blanc, of which it forms the higher elevations, it is composed of orthoclase, oligoclase, quartz, and talc,[2] and has received the designation of protogine granite, or granitoid gneiss, and was considered by the late Mr. D. Sharpe to have assumed a 'fan-shaped' structure. The granite of Monte Rosa is also of a similar composition. Granite also occurs at Brixen in the Tyrol; it forms the higher elevations of the Riesengebirge, as well as portions of the Harz, the Thüringer Wald, the Odenwald, the Schwarzwald, and the region north of the Neckar. It also occurs in Denmark and Sweden, there being large quarries north of Stockholm, and it enters largely into the great mountain chain of Scandinavia, and the dreary wastes of Finland.[3]

[1] The reader will find a large number of examples in Zirkel's Petrographie, vol. i. 476.

[2] L. von Buch, Mineral. Taschenbuch, 1824, 393. See analysis, *ante*, p. 28.

[3] A specimen of Finland granite, in the Museum of Trinity

According to Murchison, these granites are of very ancient date, geologically considered, and are generally of a rose colour, and penetrate the crystalline schists in such countless divergent veins, that geologists have generally given the mass the name of 'granitic gneiss.' On the other hand, the granites of the Uralian range of mountains are of more recent date.[1]

The use of granite for architectural purposes is splendidly illustrated in the city of St. Petersburg, to which it is brought from Finland. Here, not only the Imperial palaces and public buildings are constructed with this material, but even ordinary dwellings are partially or entirely built of it; so that St. Petersburg may be considered a city of granite. The left bank of the Neva, from the Foundry to the Gulf of Cronstadt, and both banks of the Fontanka and of the Catherine canals, are lined with high walls constructed of blocks of granite, as are the bridges over the Neva.[2] The pillars, stairs, and balconies, &c., in the palace of Cronstadt, are almost all of the finest kinds of granite, sometimes beautifully polished; and one

College, Dublin, shows the following constituents:—red orthoclase, a little greenish oligoclase (?), much black mica, and a little quartz. The specimen comes from Viborg.

[1] Russia and the Ural Mountains, i. 10.

[2] Nicholson's Dic. of Architecture, i. 474.

of the largest blocks of granite in the world, containing about 50 cubic yards of material, as I am informed by Professor O'Reilly, forms the pedestal for the statue of Peter the Great. Of this block Sir R. Murchison states that it has been reduced two-thirds of its original size, and that it was found imbedded in a bog between St. Petersburg and Cesterbeck.[1]

Gothland. This country produces a large-grained granite, consisting of chrome-red felspar, often porphyritically developed, quartz, and black mica.

Finland produces a nearly similar rock, but the felspar is of the more usual flesh colour. Specimens of these granites are placed in the Museum of Trinity College, Dublin.

Egypt. The granite of Syene ('syénite rose d'Egypte') occupies large tracts in Upper Egypt between the first cataract and the town of Assouan, the ancient Syene, including several islands both above and below the cataract. It was extensively quarried by the Egyptians as far back, at least, as the reign of Zestus, King of Thebes, 1300 years before the Christian era, and been fashioned into columns, obelisks, sarcophagi, and colossal statues which have lasted with but little injury down to the present day, and adorn the

[1] Russia and the Ural Mountains, i. 507 (note).

cities and public galleries of modern Europe. These quarries may still be traced at intervals; and the marks of the pick and chisel are still fresh.

From the specimens which have come under my own observation, both in the Louvre, in Paris, and Italian cities, the granite of Egypt, when once recognised, can scarcely be mistaken. It consists of large crystals of red orthoclase, sometimes in twins, and porphyritically developed, a little yellowish oligoclase, quartz, and dark mica, with occasionally a little hornblende.[1] Sometimes the orthoclase crystals are of very large size, and the whole rock extremely coarse-grained. The general colour of the rock is reddish, and it takes a fine polish. Its durability has been put to the proof by the sharpness of the sculpturing on the obelisks, which have in some cases lasted 3000 years. It was formerly supposed to be syenite—a rock in which hornblende replaces the mica—but De Rozière has shown this view to have been founded on error, and that the stone is a true granite; as any one may convince himself who will carefully examine the fresh fractures in the monument of the Sphinx in the Louvre. Hornblende is only an accessory, as is also garnet and pyrites. The proportion of silica is 70.25 per cent.

[1] This description agrees with that of M. Delesse, who says it is formed of quartz, orthose, oligoclase, mica, and frequently also of hornblende.—Journ. Geol. Soc. Lond. vol. vii. 9.

As regards Geological position, from the clear description of the relations of the granite to the surrounding rocks given by Lieut. Newbold,[1] and more recently by Mr. J. C. Hawkshaw,[2] it appears that this rock forms a ridge, throwing off metamorphic schists on the south, and passing under a newer formation of brown sandstone, which, according to M. Russegger, is again found with the same characters in Upper Egypt, in Nubia, and in Sinai.[3] The granite is traversed by dykes of diorite, and the metamorphic rocks in contact with it are composed of gneiss, generally the lowest, talc and hornblende schists, clay-slate and quartzite; with these are also found dykes of diorite, porphyry, and masses of serpentine. The analysis of a large piece of the granite obtained from the Egyptian Museum in the Louvre has already been given (p. 28).

Whether we consider its antiquity, or the noble monolithic works of art of which it has formed the material, we must allow the granite of Egypt to be the most remarkable of all building or ornamental stones. We cannot but admire the skill and labour which have been expended in quarrying these huge blocks, in covering them with

[1] Journ. Geol. Soc. Lond. vol. iv. 328.
[2] *Ibid.* vol. xxii. 115.
[3] Reisen in Europa, Asien und Afrika.

sculptured hieroglyphics despite the hardness of the material, and often in reducing the surface to a beautiful polish. These monuments of ancient civilization are now scattered over Europe, embellishing the cities and galleries of France, Germany, and especially Italy. Kings, emperors, and popes despoiled the ruined cities of Egypt in order to adorn the more modern cities of Rome and Paris.

One of the noblest of these monoliths is the obelisk of Luxor, brought from Egypt in the reign of Louis Philippe, and placed on a granite pedestal in the Place de la Concorde in Paris, under the direction of the engineer Lebas. According to Gwilt, its height is 79.1 English feet, with a base eight feet square. Another of these obelisks was brought to Rome by Caligula, and under Sixtus V. was placed in its present position in the centre of the Piazza di S. Pietro by the engineer Dom. Fontana, in the year 1586. Other obelisks occupy positions in the Piazza del Popolo, the Piazza di Monte Cittorio, the Piazza di Monte Cavallo, and the gardens of the Pincio. The Museums of Florence, Rome, and Naples also contain statues, urns, basins, and sarcophagi formed out of Egyptian granite.

One of the most remarkable of the Egyptian granitic monoliths is the column, one of two, which stands in the Piazza of St. Mark in Venice, and on which is perched the marble group of St. Theo-

Monoliths of red and grey Egyptian Granite, erected on pedestals of white marble, Piazza of St. Mark, Venice.

[*To face* p. 55.

dore and the crocodile. The other column, supporting the Lion of St. Mark, is of grey granite, and both are stated to have been brought to Venice from Tyre by the Doge Michielli, in the year 1127. Similar columns of grey and red Egyptian granite are still to be found amongst the ruins of Tyre—not, indeed, the ancient city of Hiram—but of the more modern imperial city, which rose to great magnificence during the Roman Empire.[1] As the former of these columns is unquestionably of Egyptian origin, so also, I believe, is the latter; for in some cases Egyptian works of art are to be found wrought in a fine-grained greyish granite, as in the case of the statue of the Sphinx in the Vatican collection. There appears, therefore, good ground for believing, that besides the red porphyritic granite, there exists in Egypt a greyish granite of ordinary composition, which, however, was less frequently used for architectural purposes and works of art than the characteristic granite of Syene; of this grey granite are some of the columns at the entrance to the portico of Saint Peter's at Rome; and probably, also, those which support the portico of the Pantheon, sixteen in number, and resting on pedestals of marble.

Obelisks and sarcophagi of red granite are found in all parts of Egypt, of which Pompey's Pillar, and

[1] See Tristram's Land of Israel, p. 53 (1866).

Cleopatra's Needle at Alexandria are examples. The stone was used for the inside polished lining of the Great Pyramid of Cheops,[1] and the monolith sanctuary of Sais; and as the seats of government successively approached the Mediterranean, we find that the materials necessary to the construction of sacred and palatial buildings were transported farther down the valley of the Nile from their sources in the neighbourhood of the cataracts.

[1] Piazzi Smyth, Quart. Journ. Science, vol. xxx. 191; Nicholson's Dic. Arch. vol. i. 474. A small urn of Egyptian granite, finely crystalline white felspar, and black mica, is in the Royal College of Science, Dublin.

CHAPTER VI.

GRANITES OF AMERICA.

North America. Granite is largely developed in some portions of the Rocky Mountains, and north-eastern portions of the American continent. Massachusetts, Rhode Island, New Hampshire, and Main are the principal sources of this rock in the United States. The so-called Chelmsford granite comes from Westford and Tyngsborough, beyond Lowell, and an excellent variety is obtained at Pelham, a short distance north in New Hampshire. Masses sixty feet in length are obtained at several of the quarries, and are worked into columns for buildings for the cities of New York and Boston. The new Exchange, considered to be the finest public building in New York, is built of granite, probably from New Hampshire. Good granite is also quarried in Waterford, Greenwich, and elsewhere in Connecticut.[1]

Lower Canada. Granite is extensively used for buildings, and is quarried at Stanstead, Barnston, and Nicolett.

[1] Dana, Man. of Mineralogy, 352 (1870).

The granite of Stanstead is of a greyish hue, uniform texture, and can be extracted from the quarry in large blocks. A beautiful variety also occurs at Barford.[1] It is also extensively developed in various parts of Nova Scotia and New Brunswick.[2]

India. Granite occurs amongst the higher altitudes of the Nepal Himalayas.[3] It is also widely distributed over portions of India, accompanying gneissose and other metamorphic rocks, as at Trichinopoly, Nerbudda, and the sub-Himalayan district between the Ganges and the Ravee. It is often used (in company with gneiss) as the stone for the basement story of Hindoo temples. In the Shillong district, it has a composition, according to Mr. Medlicot, much resembling that of many places in Europe, the favourite quaternary assemblage of pink orthoclase, often in large crystals, pale greenish felspar (probably oligoclase), hyaline quartz, and dark green mica.[4]

[1] Logan, Geology of Canada.

[2] Dawson, Acadian Geology, Geol. Map.

[3] Hooker, Himalayan Journal, vol. i. ch. 11.

[4] 'Geology of the Shillong Plateau,' Mem. Geol. Survey, India.

CHAPTER VII.

SYENITE.

According to the views of most British, and some Continental geologists, as Brongniart,[1] syenite is a crystalline granular aggregate of quartz, felspar, and hornblende, differing from granite only in the substitution of the last-named mineral for mica.[2] On the other hand, most Continental petrographers consider the quartz as unessential, in which case it is simply a binary compound of orthoclase felspar, and hornblende,[3] the rock of the Plauenschen Grund, near Dresden, being eminently characteristic.

According to this view, the distinction between syenite and diorite lies in the difference of the felspars, which in the latter may be oligoclase, labradorite, or albite, but not orthoclase. This may be a good distinction in theory, but in practice it is generally impossible, by the ordinary process of ex-

[1] Classif. des Roches, p. 69 (1827).

[2] Jukes' Manual of Geology, 3rd edit. 124; Ramsay, Descrip. Catalogue M. P. G. p. 241; Sir H. De la Beche, Geological Observer, p. 585; R. Hunt, Descrip. Guide Mus. Prac. Geol. 3rd edit. p. 21; J. Phillips, Mem. Geol. Survey, vol. ii.

[3] Zirkel, Petrog. i. 578; B. von Cotta, Eng. Trans. p. 178.

amination,[1] to determine the nature of the felspar, whereas the presence or absence of free silica in a rock composed of hornblende and felspar may generally be determined by the aid of a lens. For this reason I prefer to hold by the British definition; as it is more available for observers in the field.

Varieties. Granite, by the appearance of hornblende crystals, gradually replacing those of mica, passes in rare instances through the stages of syenitic-granite into syenite; instances of which are to be found amongst the Carlingford, and Slieve Croob mountains in the north-east of Ireland, and amongst the Vosges mountains on the east of France.[2] Syenite cannot be considered as an eruptive rock of frequent occurrence.

England. Jersey and Guernsey, sometimes as syenitic-granite, or passing into porphyry.[3] The Malvern Hills, Worcestershire, where it consists of reddish felspar, quartz, hornblende, and sometimes epidote; the rock is beautiful and varied.[4] Mount Sorel, Leicestershire, as syenitic granite, rose-tinted, hard, and durable, and largely quarried for architectural purposes of an ornamental character. It is formed

[1] That is, by means of a pocket lens, or the eye. The determination of the felspar may generally be obtained by microscopic examination of translucent slices.

[2] Delesse, Ann. des Mines, vol. xix. 150 (1851).

[3] McCulloch's Geog. Dic.

[4] Phillips, Mem. Geol. Survey, vol. ii. part i. 40, 41.

of reddish felspar, green hornblende, a little quartz and mica. There are, however, variations from this the typical constitution.[1]

Wales. Mynyd Cefn, Amwlch, near Pwllheli, N.W. of Ffestiniog, Pen-ar-fynydd, three miles east of Abardaron.

Ireland. At Loughrusmore a large-grained syenite (or diorite) is found consisting of a crystalline granular aggregate of hornblende and felspar. Analyses of four varieties of syenite from Co. Donegal, by the Rev. Dr. Haughton, gives the proportion of silica as ranging from 49.2 to 58.05 per cent.

In Carlingford mountain there occurs a handsome variety of 'anorthite syenite,' composed of anorthite felspar and hornblende.

Scotland. Strontian, Argyleshire; syenitic granite and syenite. Ben Glamich, Island of Skye.

The Continent. A very handsome syenite is found in the Dresdner Falsterstein, the constituents of which are reddish felspar, hornblende, and a little quartz. A specimen is placed in the Museum of Trinity College, Dublin.

Canada. Syenite, of handsome appearance and good quality for architectural purposes, occurs at Grenville. It consists of deep red orthoclase felspar, greenish-black hornblende, and grains of quartz in small quantity. A similar rock is also found at

[1] Specimen in Museum of Trinity College, Dublin.

Chatham, and Wentworth, and at Barrow Island in the St. Lawrence.[1]

Nova Scotia. Syenite, in company with porphyry, suitable for building and ornamental purposes, is extensively developed amongst the Cobequid Mountains, and on the east side of Bras d'Or; but owing to the inland position of the former locality, and the absence of local demand, it is not at present turned to much use.[2]

[1] Logan, Geology of Canada.
[2] Dawson, Acadian Geology, p. 593.

PART III.

PORPHYRITIC ROCKS.

CHAPTER I.

PORPHYRIES.

Specific gravity, 2.49–2.60. Porphyr (*Germ.*) Porphyre (*Fr.*)
Proportions of silica in quartz-porphyry . . . 70–81 per cent.
„ „ in porphyrites (basic) . . 59–61 „

THE term 'porphyry' was originally applied to certain kinds of igneous rocks of reddish or purple tints, such as the red porphyry of Egypt,[1] but this primary signification has now given place to one in which structure, and not colour, is the guiding characteristic.

A porphyry, as the term is now generally received, is a rock of plutonic origin, with a compact, or micro-crystalline, felspathic base, in which individual crystals of quartz, or felspar, sometimes with other minerals, are developed. Thus we have the following varieties:—

(*a*) *Quartziferous porphyry;*[2] a finely crystalline

[1] Mr. R. Hunt, Descrip. Guide M. P. G. 3rd edit. p. 20.
[2] This is the felsite porphyry of Zirkel.—*Ibid.* i. 530.

granular felspathic rock, with individual crystals of silica and felspar.

(*b*) *Felstone-porphyry;* a compact or micro-crystalline highly silicated felspathic rock, with individual crystals of felspar.

(*c*) *Porphyrite;*[1] a quartzless porphyry or basic felstone, with individual crystals of felspar.

Chemical Analysis. The following are several analyses of porphyries, including both the quartziferous and quartzless varieties:—

Analyses of quartziferous porphyries (acidic).

	I.	II.	III.	IV.	V.	VI.
Silica	74.44	81.05	67.54	72.33	70.50	72.20
Alumina	13.51	11.49	14.97	8.97	13.50	12.50
Oxides of Iron	2.25	2.28	5.14	7.46	5.50	3.70
Lime	1.19	0.40	2.84	1.98	0.25	0.90
Magnesia	0.01	0.40	1.30	trace	0.40	—
Potash	5.31	2.07	4.58	1.46	5.50	3.88
Soda	1.40	2.56	2.28	5.83	3.55	5.30
Water	1.34	0.93	1.08	1.86	0.77	0.60
	99.45	101.18	99.73	99.89	99.97	99.08

I. Quartz-porphyry (or felsite-porphyry) from the Harz Mountains.

II. Quartz-porphyry (or felsite-porphyry) of Falkenstein, near the Donnersberg in the Palatinate.[2]

III. Quartz-porphyry from the flanks of the Bodenthal, below Lucashof, with quartz, orthoclase, and oligoclase. Sp. gr. 2.66.[3]

[1] A name proposed by Naumann (*Geognosie*, i. 600); with him Von Cotta (*Gesteinslehre*, p. 105, 1862); Zirkel's name is 'quartzless orthoclase porphyry' (*quarzfreier orthoklas Porphyr*), *ibid.* i. 596.

[2] Bischof, Lehrb. der phys. Geol. 1862.

[3] Streng, N. Jahrb. für Miner, p. 267, 1860.

IV. Elvanite (quartz-porphyry), Co. Wexford, Ireland. J. A. Phillips, Phil. Mag., June 1870.

V. Reddish porphyry from Kreuznach.[1]

VI. Rose-coloured quartziferous porphyry ('orthophyre') from Grenville, Canada. Sp. gr. 2.0.[2]

Analyses of Porphyrites (basic).

	I.	II.	III.
Silica	59.17	63.82	55.29
Alumina	19.73	15.14	18.78
Iron oxide	1.71	5.37	9.46
Lime	3.92	2.65	3.14
Magnesia	0.40	1.24	3.48
Soda	3.54	4.04	8.68
Potash	4.03	4.56	
Water and loss	3.40	1.54	1.17
Carbonic acid	2.52	—	—
	98.42	98.36	100.00

I. Boscampo Bridge, near Predazzo, Tyrol. Kjerulf, Christiania Silurbecken, 1855, 14.

II. Dyke in largely-crystalline 'syenite.' Flesh-coloured base, with crystals of orthoclase, a few of light grey oligoclase, and greenish grains, probably of hornblende. Kjerulf, *ibid.* 15.

III. Dark grey felspathic base, with rhomboid crystals of felspar ('Rhombic-porphyry').

Geological Ages. The highly silicated quartz-porphyries and felstone-porphyries have been chiefly developed amongst rocks of Primary, or Palæozoic age, and are largely developed amongst the mountainous districts of the British Islands, formed of these rocks; such as Galway, Sligo, and Donegal in the West and North of Ireland, and Wexford and

[1] Wolff, 'Dic. d'Anal. Chim.,' par Violette et Archambault.

[2] Sterry Hunt, 'Logan's Geol. of Canada,' p. 654.

Wicklow in the East; in North Wales; Cumberland; the Southern Uplands and Highlands of Scotland; Devonshire and Cornwall in the South of England. They are also found penetrating the old crystalline rocks of Scandinavia; the chain of the Oural mountains in Russia; and the crystalline rocks near the first cataract of the Nile.

CHAPTER II.

BRITISH PORPHYRIES.

Scotland. In this country porphyries are found imbedded with the Lower Old Red Sandstone, of the Sidlaw and Lammermuir Hills; with the Upper, in the Pentlands;[1] and in the vicinity of Lesmahagow.[2] One of these finely crystalline rose-coloured porphyries from this neighbourhood, which would make a beautiful stone for ornamental purposes, appears from examination under the microscope to be composed of red orthoclase and triclinic felspars, small hexagonal scales of greenish mica, and a few grains of quartz. Jameson mentions the occurrence of a beautiful porphyry, penetrating mica slate between Blair Athol and Dalnacardoch.[3] A handsome porpyhry, according to Dr. Bryce, occurs along the S.W. coast of the Island of Arran.

Cornwall is rich in porphyritic rocks,—many of the elvan dykes assuming this character—having a highly silicated felspathic base, with crystals of

[1] Geikie, 'Chron. Trap Rocks of Scotland,' Trans. Roy. Soc. Edinb. xii. 635.

[2] Described by Sir R. Murchison, Quart. Journ. Geol. Soc. xii.

[3] Syst. Mineralogy, iii. 137.

felspar and quartz, sometimes schorl, and rarely mica. One of the most remarkable examples is the schorlaceous porphyry from Luxullian, in Cornwall; consisting of black schorl and a little felspar and quartz as a base, in which are distributed large crystals of red orthoclase felspar. The sarcophagus for the late Duke of Wellington, now in St. Paul's, is formed of one huge mass of this rock, which has received the name of Luxullianite.[1]

A handsome porphyry, suitable for polishing, may be obtained from Tremore, near Bodmin. It occurs as a dyke, extending in an easterly direction from this place to the south of Withiel and St. Wenn. The rock varies in colour, but those portions having a reddish or flesh-coloured base, with crystals of white felspar, and occasionally some schorl and quartz, are the most beautiful, and occur in large quantity at Tremore village, and in a ravine above Ruthan bridge. This porphyry has been cut and polished by water power at Fowey Consols Mine, for private use; and it has a very handsome appearance, with the additional advantage of being capable of extraction from the quarry in large blocks. Another variety from the same neighbourhood is composed of light pink crystals of felspar, with others of quartz and schorl, in a brownish-red felspathic base; and a third (but apparently only occurring in small quantity) is

[1] Mr. R. Hunt, Descrip. Guide Mus. Prac. Geol. p. 20.

formed of greenish felspar crystals, in a light, flesh-coloured base,—a combination of extremely rare occurrence.[1]

A very beautiful reddish elvanite (a granitoid variety of quartz-porphyry) is found at Barton and Ennis, near the Indian Queen Inn, between Bodmin and Truro. Good varieties may be obtained from some of the Gwennap elvans; that at Seveock Water, near Chasewater, with a grey granitic base, containing crystals of roseate felspar, and nests of radiating schorl, being specially worthy of notice. Other localities for ornamental porphyries, which may be mentioned, are Mayon, near the Land's End; a rose-tinted rock between Tyecombe and Dowgas, near St. Austell; others near Camelford, and between Penhale and Bochin, which latter is composed of white felspar crystals, in a very dark green base; and lastly, the porphyritic greenstone of Boswednon Cliff, near Zennor.[2]

The trap rocks here described either penetrate the stratified rocks in dykes, or occur as intrusive sheets nearly coinciding with the bedding, or strictly conformable to them. In North Wales, on the other hand, they form beds of great horizontal extent and thickness, rising into the higher elevations, and following all the inclinations and flexures of the lower

[1] Sir H. T. De la Beche, Geol. of Devon and Cornwall, p. 502.

[2] *Ibid.* pp. 156–192.

Silurian grits and slates with which they are truly interbedded; while enormous bosses protrude here and there through the sedimentary strata (as, for example, at Penmaenmawr), which may be regarded as portions of the old throats of the ancient volcanoes, from which these great lava streams—probably submarine—were poured forth.[1]

The porphyrites, accompanied by melaphyres, are, for the most part, found imbedded amongst rocks of Devonian, Carboniferous, and Permian age, having been erupted and poured out in a liquid state over the bed of the sea in which these strata were in course of deposition, accompanied by volcanic ashes, scoriæ, and agglomerate; and thus presenting, as regards their mode of occurrence, the phenomena of more recent volcanic regions. In this manner, these basic plutonic rocks underlie the coal-measures of Scotland, and rise from beneath the coal-basin of the Clyde in terraced escarpments, forming the hills of Kilpatrick, Campsie, and Kinross on the north; and of Largs, Gleniffer, and Neilston on the south; but finding their noblest exemplification in the mural cliffs of Arthur's Seat and Salisbury Crags, near Edinburgh.[2] These rocks are exceedingly varied

[1] Ramsay, Geol. Survey Memoir on North Wales; Sedgwick, Quart. Journ. Geol. Soc. iii. 133, and iv. 216.

[2] Murchison and Geikie, Geol. Map. of Scotland, text, p. 13; Geikie, 'Geology of Edinburgh,' Mem. Geol. Survey, p. 33.

in appearance, and contain numerous minerals, such as stilbite, prehnite, analcime, calc-spar, glassy quartz, &c.

Ireland. In the South of Ireland, the porphyrites and porphyries of the Carboniferous basin are of a similar character to those in the centre of Scotland, forming two concentric zones, interstratified with the Carboniferous Limestone;[1] in some places they assume the aspect of melaphyres. A very handsome porphyry (or porphyrite) is found at Lambay Island, off the eastern coast of Ireland, which is scarcely inferior in beauty to the porphyry called 'verde antico,' so frequently employed for decorative purposes on the Continent.[2] It consists of a dark green base, in which numerous light green crystals of orthoclase felspar are distributed. This rock takes a fine polish; a large block has been placed for exhibition in the Museum of the College of Science, Dublin, which deserves the attention of architects and sculptors.

[1] Maps of the Geological Survey of Ireland, 144 and 154, with Explanatory Memoirs by Messrs. Jukes, Kinahan, and O'Kelly. Mr. S. Allport is now engaged in an examination of these rocks from the Limerick basin under the microscope, from which some interesting results may be anticipated.

[2] Especially Italy. See p. 73.

CHAPTER III.

PORPHYRIES OF THE CONTINENT.

Sweden. At Elfdahlen, in the province of Delicarbia, great varieties of porphyritic rocks are developed. One of these exhibits red, blue, violet, and grey colours, and contains in addition to crystals of felspar, others of garnet, titanite, magnetite, specular iron ore, and pyrites. It is manufactured into small ornaments.[1] This rock is extensively developed in the south of Norway. At the same place, mosaics of great beauty are produced, and fine specimens of ornamental art;[2] amongst which may be mentioned the large and beautiful vase placed in front of the Palace of Rosendal, near Stockholm; and the sarcophagus enclosing the remains of King Charles John.

Germany. In Saxony, Thuringia, Westphalia, and the southern borders of the Harz, porphyries sometimes contemporaneous with the Permian formation, sometimes irruptive, are largely developed, and occur both as quartziferous, basic, and amygdaloidal.[3] The

[1] B. von Cotta, Petrog. p. 170.

[2] A tazza of one of these porphyries is in the collection of the Royal College of Science, Dublin.

[3] Murchison and Morris, 'Rocks of the Thuringenwald,' &c., in Journ. Geol. Soc. Lond. xi. 420.

porphyry of the Lenne-Gebiet in Westphalia bears a close resemblance to that of Elfdahlen.[1]

France and Belgium. The most important porphyries are those of Lessines and of Quenast, of almost the same composition, and both used extensively in pavements for the streets of Paris and other cities. They are composed of a felspathic base (oligoclase) with chlorite, mica, hornblende, and sometimes quartz. The quarries at Lessines were opened in 1750, and now have attained a depth of about fifty-two metres.[2]

The structure and composition of these porphyries have been determined and described by Professor Delesse.[3]

Greece. The *Marmor Lacedæmonium viride* of Pliny (Nat. Hist. xxxvi), is a material which has been largely used in Italian decorative architecture from very ancient times, as well as in Greece itself. The ancient quarries were situated, and have been recognised, between Sparta and Marathon. It consists of a dark-green felspathic base with imbedded light-green crystals of felspar. M. Delesse, who has subjected the stone to close examination,[4] finds it to

[1] B. von Cotta, Petrog. p. 107.

[2] Delesse, Matériaux de Construction de l'Exposition Universelle de 1855.

[3] Journal of the Geological Society of London, vol. vii. 7.

[4] Annales des Mines, p. 256.

be composed of Labradorite felspar and augite with grains of titano-ferrite: it would therefore appear to be a species of basalt-porphyry.

This stone is much employed in pavements, and inlaid-work in the Italian churches. Along with blocks of grey lava and Egyptian porphyry, it is used in the pavement of the Piazza of St. Peter's, Rome; and in the Museum of the Vatican, a crab and a lobster, each of the largest size, sculptured in this green porphyry, have been deposited.

Corsica. A peculiar species called 'Corsican porphyry' is derived from this island; it is, however, rather an amygdaloid. But much more remarkable is the 'orbicular greenstone,' or 'Napoleonite,' in which the two constituents of felspar and hornblende are concentrically arranged, enveloping in alternate folds of irregular shape a crystalline granular centre. When cut into slabs or ornaments, the arrangement of the minerals produces a series of rings, of varying outline, pressed together, and adapting themselves the one to the other. It is probable that in this structure we have an illustration of the globular form which basaltic and trappean rocks often tend to assume.[1]

[1] A tazza of Napoleonite is in the Museum of the College of Science, Dublin; and Mr. A. Gages has determined the proportions of the minerals as follows:—Anorthic felspar 90 p. c., hornblende 10 p. c.

CHAPTER IV.

EGYPTIAN PORPHYRY.

Egypt. Of all the porphyries which have been employed in sculpture, none are so celebrated as the 'roseo antico,' or red porphyry of Egypt. This stone has been wrought from very distant times from quarries situated near the first cataract of the Nile,[1] and has been fashioned into huge statues of deities, and sphinxes, and other objects, by the ancient Egyptians, while it was largely used by the Romans for vases, sarcophagi, and even for statuary purposes. With the decline of the Roman Empire, the art of cutting and polishing porphyry seems to have been nearly lost, but was revived by the Florentines under the De Medicis during the middle ages. The palaces, churches, and galleries of Italian cities are abundantly supplied with marvellous examples of industrious skill as applied to sculpture in Egyptian porphyry, a few of which shall presently be noted.

Mineral Characters. Judging by the general similarity of the material in the cases of objects formed out of this porphyry, whether we find them in

[1] As I am informed by Dr. Stanley, Dean of Westminster.

England, France, or Italy, it seems to be remarkably uniform in texture and composition. It consists of a reddish-brown or chocolate-coloured felspathic base, in which small crystals of nearly white felspar are abundantly distributed. According to Chateau,[1] the cutting of this rock is attended with much difficulty owing to its hardness; and we cannot, therefore, but feel admiration for the patience and skill which must have been expended in fashioning some of the large and elaborate objects of art which have been formed of this material. As examples of a few of the uses to which Egyptian porphyry has been applied, may be mentioned, first: the great circular basin, twelve feet in diameter by my own measurement, and four feet in depth, which stands in the Sala Rotunda of the Vatican Museum; and the two massive sarcophagi of sculptured and polished porphyry, one of these having been taken from the tomb of Constantia, daughter of Constantine the Great, in the same collection.

Inside the principal entrance to St. Peter's, and inserted in the beautiful marble floor of the cathedral itself, may be seen a circular slab of Egyptian porphyry, on which the emperors were formerly crowned. It is therefore regarded with the same veneration that we attach to the rock of Scone on which the kings of Scotland used to be crowned,

[1] Technologie du Bâtiment, ii. 451.

and which is now placed in Westminster Abbey.[1] In the same church is the cover of a sarcophagus of polished porphyry from the Mausoleum of Hadrian, now converted into a font. It is about twelve feet in longest diameter, and is probably one of the largest blocks of this rock in Europe.

Objects in Egyptian porphyry have been found in the ruins of Pompeii, some of which are preserved in the Museum of Naples; and both in this, and in the Gallery of the Pitti at Florence, are large basins formed of identical material.

Amongst the more unusual purposes to which Egyptian porphyry was applied, and not unsuccessfully, was in the draping of figures and statues. In the Lateran collection at Rome there is a statue of a Roman, found in the Forum, draped in garments of porphyry. But the most successful of all these examples I have seen, is the figure of Apollo in a sitting posture in the Museum of Naples. It is larger than life size, the head, hands, and feet are of white marble, while the robe is of Egyptian porphyry.

CONCLUDING OBSERVATIONS.

Architectural and Ornamental Uses. Notwithstanding the great beauty of the darker porphyritic rocks,

[1] An account of this stone, which the Rev. Dr. Haughton, F.R.S., informs me is a boulder of Old Red Sandstone, is given by Dean Stanley, in his Memorials of Westminster Abbey.

and their high value in ornamental work, their effect, when used as building stones on a large scale, is not pleasing. A house built of a dull purple, a reddish, or a greenish stone, has always a heavy and gloomy aspect, which ought to be chased away as much as possible from the abodes of men. When thus used in large masses, the special beauties of porphyries, which only appear on close scrutiny, are lost; but, on the other hand, when judiciously used for ornamental purposes, or for relieving by contrast large surfaces of light-coloured building material, these stones then assume their true place in architecture.

It must also be recollected, that porphyries require a polished surface in order to the full display of their colours. This polishing process is necessarily beyond the reach of most individuals, and it is therefore only in their rough state that they can be employed for the walls of houses and larger buildings, a use to which, as already remarked, they are not well adapted.

The special use, therefore, of the more beautiful varieties of porphyry is for ornament, or relief in buildings of freestone; while the commoner kinds furnish valuable paving stones, or road-materials, and may be used where resistance to wear and tear are the main purposes for which they are employed.

PART IV.

GREENSTONE ROCKS, &c.

CHAPTER I.

DIORITE, DIABASE, MINETTE, &c.

Generally called Greenstones.

The rocks which come under the above heads cannot be considered as generally suited for architectural, and only exceptionally for ornamental purposes, and consequently might have been passed over in silence in this work, which properly extends only to rocks of this description. In adopting this course, however, an hiatus would have occurred unexpected by some readers, and inconvenient to the student; and I therefore propose to give a short account of the origin, nature, and uses of a group of rocks which is very largely distributed over the earth's surface.

Origin. Though greenstones and basalts are both of igneous origin, and similar in general appearance, yet they may be considered as the representatives of two great classes, differing in composition and gene-

rally in geological age; the greenstones (or diorites, &c.), being essentially hornblendic, and the basalts, augitic; and while the former have generally been irrupted in the Palæozoic ages of geological time; the latter (with rare exceptions) are of Mesozoic and Tertiary ages.[1] We shall, therefore, consider them under two heads.

Greenstones. This much used, but much abused, name is strictly confined to the group of plutonic rocks which includes *diorite, diabase, gabbro,* &c., and has, therefore, only a generic signification; its most important specific constituent being diorite.

Diorite. (Diorit, *Germ.*) Specific gravity, 2.6–2.9; contains silica 47–58 per cent. It is a basic plutonic rock, crystalline granular to micro-crystalline, generally of a greenish colour, and composed of albite, oligoclase, or anorthite felspar, and hornblende,[2] and often with epidote, chlorite, pyrite, and other minerals as accessories. Occasionally mica makes its appearance; and instances may be found where this mineral replaces the hornblende in a different part of the same rock, thus converting it into minette or mica-trap.

Diorite is found amongst Silurian, Cambrian, and metamorphic rocks, generally in the form of dykes,

[1] Amongst these exceptions are some of the basaltic dykes of the Mourne Mountains, in Ireland.

[2] Zirkel, Petrog. i. 450. Delesse has recognised labradorite and anorthite as entering into the composition of diorite.

intruded partially along the planes of bedding; at other times crossing them transversely and vertically. In the former case, it often assumes a bedded aspect, and a columnar structure, in which the axes of the columns are at right angles to the planes of cooling; an example of which may be observed on the northern flank of Cader Idris mountain in Wales.[1]

Diorite is generally extremely hard and tough, and is consequently well suited for road-material and paving. The Penmaenmawr stone of North Wales, which may be called a felspathic greenstone,[2] is shipped to all parts of the British Isles for paving. The rock, which is finely crystalline granular, composed of felspar and hornblende, is intersected by a great number of parallel joints, along which it splits into small blocks of a size suitable for street paving. Its hardness and durability are extreme. Bardon Hill, in Leicestershire, also affords a stone of similar qualities, but of more variable composition,[3] which is distributed for road metal over a large part of the central counties of England.

It is now becoming thoroughly understood that it

[1] These modes of occurrence are well illustrated by the maps and sections of the Govt. Geological Survey of Great Britain.

[2] Descrip. Catal. Rocks M. P. G., p. 202.

[3] This rock varies from a felstone porphyry to a diorite or greenstone, and from this to syenite, composed of hornblende, felspar, and quartz. Hull, 'Geology of the Leicestershire Coal-field.' Mem. Geol. Survey, p. 13, 1860.

is more economical in the end to use a hard stone of the greenstone type for roads, though the first cost may be considerable, rather than a soft stone, which though cheap at first, may be perishable; just as steel rails for railways have proved their superiority in the matter of cost, in the long run, though at first much more expensive than rails of rolled iron.

The following are analyses of three specimens of diorite from the 'Sanctuaries,' St. Mewan, Cornwall:[1]

	I.	II.	III.
Silica	47.66	47.32	47.79
Alumina	17.50	17.15	17.83
Oxide Iron	21.94	22.60	22.49
Lime	4.20	4.03	4.10
Magnesia	trace	trace	trace
Potassa	2.43	2.33	2.15
Soda	5.19	5.27	5.88
Sulphur	trace	trace	trace
Phosphoric Acid	0.16	0.18	trace
Titanic Acid	trace	trace	trace
Water	0.83	0.18	0.76
	99.91	99.70	99.91

GABBRO. A name proposed by L. von Buch for a rock composed of labradorite and diallage, smaragdite, or hypersthene, and usually some other minerals.[2] It is variable in composition, and not of frequent occurrence.

DIABASE. (Hyperite, Scandinavian Trap.) A crystalline-granular compound of oligoclase, labradorite,

[1] Phil. Mag., Feb. 1871.
[2] B. von Cotta, Eng. vers. p. 150.

albite, or anorthite, with pyroxene and chlorite; in its fresh state, dark-green. Sp. gr. 2.7–2.9; contains silica 43–56 p. c. Diabase was first raised to the rank of a separate rock, and distinguished from other greenstones by Haussmann. It occurs near Berneck, and Saalburg, both in the Fichtelgebirge.[1]

In Co. Mayo, a peculiar class of rocks occurs, composed of orthoclase felspar, augite, and chlorite; thus differing from diabase in the species of the constituent felspar. Magnetite is also present, and when the felspar crystals are porphyritically developed it has a very handsome appearance. Of this rock some hills near Swinford are formed.

MICA-TRAP. (Minette, *Fr.* Glimmertrapp, *Germ.*) In this place I insert the rock of the above name; notwithstanding that, according to Zirkel, the felspar is essentially orthoclase,[2] because it occurs amongst the geological formations in a manner precisely analogous to that of diorite, and seems to represent this rock over special districts. It is composed of orthoclase felspar, mixed with much mica, and occasionally hornblende, pyrites, &c., as accessories; it is generally tough, and weathers rusty brown.

Minette occurs in the form of intrusive dykes or beds, amongst the Silurian rocks of Wicklow, Cavan, Monaghan, and Down; also in Co. Wicklow and

[1] B. von Cotta, Eng. version, p. 146.

[2] Petrog. i. 450; also B. von Cotta, Rocks, Eng. vers. p. 174.

other parts of Ireland, as near Louisburg, Co. Mayo. In Scotland also it is found amongst the Silurian rocks of the Southern Uplands, apparently continuous with those of the North of Ireland already described. Amongst the Silurian rocks of Wales, however, it is of rare occurrence, and seems to be represented by hornblendic rocks. It is of frequent occurrence, also, amongst the Lower Silurian strata of Cumberland and Westmoreland, appearing on both sides of the Valley of the Eden, associated with slates and grits of the Skiddaw and Helvellyn groups. On the Continent, it is met with to a considerable extent near Framont, in the Vosges mountains; near Oederan and Dippoldiswalde, in Saxony, it penetrates beds of gneiss.[1] Except as a material for mending roads, or making rough walls, it is useless for any economical purpose.

[1] B. von Cotta, Rocks, Eng. version, p. 174.

CHAPTER II.

AUGITIC ROCKS.

Basalt, Dolerite, and Melaphyre. These rocks are partly plutonic, partly volcanic; *i.e.*, they have been irrupted into the stratified rocks at considerable depths, either in sheets or dykes; or else poured forth at the surface, or over the bed of the sea, from volcanic vents. These augitic rocks are, for the most part, of Tertiary or Recent age; but they have their representatives amongst the Carboniferous and Permian formations, such as the melaphyres. Generally, however, it may be affirmed that the augitic rocks are more modern than the hornblendic, and were not irrupted till towards the close of the Palæozoic or Primary epoch of geological history.

Dolerite is a name given by Von Hauy, from the Greek δολερὸς, on account of its deceptive resemblance to diorite.[1] It is a crystalline granular compound of Labrador felspar and augite, with a little titaniferous magnetic iron-ore, in crystalline grains or groups; generally oxide of iron, olivine, and lime are present as accessories. The components felspar and augite are sufficiently large to be distinguished by the naked eye.

[1] Zirkel, Petrographie, ii. 273.

A variety of the same rock, in which the crystalline structure is scarcely perceptible, has received the name of 'anamesite' from Continental petrologists, after Von Leonhard; but it cannot be regarded as important, the size of the crystals being probably only due to different rates of cooling.[1]

Basalt. This rock is a dark, apparently homogeneous rock, in which the components are invisible to the eye, but under the microscope are found to consist of minerals similar to those of dolerite, namely, labradorite felspar, augite, and titano-ferrite.

Amongst the most frequent accessories of the modern or Tertiary basalts, so as almost to appear an essential, is olivine. They also frequently contain carbonate of lime; and when amygdaloidal, the cells are sometimes filled with calcareous spar, or zeolites, probably formed by filtration after the consolidation of the rock itself. Werner found vesicles of water in compact basalt of Germany; and Dr. Richardson, similar water-cells in that of Antrim.

From the compact character of the rock, it was long supposed that basalt was a simple mineral substance, until Cordier, in 1815, examined under the microscope the pulverized grains, and recognised in them the constituents of dolerite. His observations

[1] Zirkel's recent work on the Microscopic Structure of Basaltic Rocks (Untersuchungen über die mikros. Zusammensetzung der Basaltgesteine).

were afterwards confirmed by Hessel, by deduction from analysis.[1]

Mode of Occurrence. Basalts and dolerites occur under three general modes. 1. As vertical dykes. 2. As sheets or beds intruded amongst older rocks. 3. As tabular sheets poured over the surface, and forming horizontal or inclined beds, often interstratified with volcanic ashes, agglomerates, and bands of bole. The following may be adduced as examples:

1. *Vertical Dykes.* These are extremely numerous over the North-East of Ireland, the North of England, and the centre of Scotland; traversing rocks of different geological ages, from the Silurian to the Oolitic. They everywhere radiate from the great basaltic region of Antrim and the inner Hebrides; and Professor Geikie has come to the conclusion that they are all referable to the same Tertiary period with the volcanic rocks of this region itself.[2] There are, however, in the North and East of Ireland, basaltic dykes of much older date.[3]

2. *Intrusive Sheets.* These are prevalent amongst the Carboniferous rocks of Ayrshire, the Clyde basin, and other parts of Scotland. Sometimes they are unexpectedly met with in mining researches, and are often passed through in coal-pits. At other times, they rise

[1] Zirkel, Petrog. ii. 282.

[2] Address to Geological Section Brit. Assoc. Dundee, 1867.

[3] Hull and Traill, 'On the Plutonic and Granitic Rocks of the Mourne Mountains,' Brit. Assoc. Rep. Edinb. 1871.

into ridges and escarpments of considerable elevation; and amongst these may be specially named the ridge on which is situated the Glasgow Necropolis, and the bold mural escarpment of Salisbury Crags.[1]

3. *Tabular Sheets.* In the North-East of Ireland, extending from the northern shore of Belfast Lough on the south, to the precipitous cliffs of Fair Head and the Giant's Causeway, we have one of the grandest exhibitions of sheets of basaltic and doleritic rocks in the British Islands. Here the different lava-flows of Lower Miocene age are consolidated into several successive beds of hard, generally columnar trap, separated by irregular beds of bole, ochre, volcanic ash, and agglomerate, the whole attaining a thickness of nearly 2000 feet. These rocks reappear in the Isles of Mull and Staffa, and are considered by Mr. A. Geikie to be continued through the Faroë Islands into Iceland, where the volcanoes, long since extinct in Britain, are still in activity.[2] In texture and composition, these basaltic rocks are extremely variable. In some places they are soft, earthy, and amygdaloidal; in others compact, or highly crystalline. In the largely crystalline dolerite of Fair Head, in Antrim, the ordinary augitic mineral is replaced by hypersthene. A similar hypersthenic dolerite

[1] Geikie, Geol. of Edinb. Mem. Geol. Survey, p. 22 (1861).
[2] Address, Brit. Assoc., 1867.

forms the upper portion of Scrabo Hill, Co. Down.[1] Here and elsewhere the sheets of basalt are often traversed by vertical dykes. The following are analyses of the rock at points over the region here described:—

	I.	II.	III.
Silica	52.13	47.80	46.80
Alumina	14.87	14.80	14.40
Oxides of Iron	11.40	13.08	12.20
Oxides of Manganese	0.32	0.09	2.80
Lime	10.56	12.89	10.16
Magnesia	6.46	6.84	9.53
Potash	0.69	0.86	1.16
Soda	2.60	2.48	
Water	1.19	1.41	3.00
	100.22	100.25	100.05

I. Fine grained dark green 'anamesite,' from the Giant's Causeway.[2]

II. Fine grained dark green 'anamesite,' from Fingal's Cave, Staffa.[3]

III. Greyish hydrated 'anamesite,' from the Faroë Islands.[4]

Basalt, &c., of foreign countries. Sheets of basalt are developed in the volcanic region of Auvergne, in Central France; the district of the Eifel, and Siebengebirge on the Lower Rhine; in the Mittelgebirge, in Bohemia, reaching 2,920 feet; at Marksuhl, near Eisenach; at Unkelstein, near Frankfurt; and in the Riesengebirge, in Silesia. At Vicenza, in Italy, ten

[1] For the determination of this mineral I am indebted to Mr. A. Gages, M.R.I.A.

[2] Streng, Poggend. Ann. xc. 1853, 114. [3] Streng, *ibid.*

[4] Durocher, Annal. des Mines, xix. 559. The 'Whin Sill' of the Pennine Ridge is an example of a contemporaneous basalt of the Carboniferous period in England.

beds of basalt occur, interstratified with an equal number of Tertiary limestones;[1] and in the Pic de Teyde, Teneriffe, this rock alternates with obsidian and trachyte. In Canada, the more modern basalts constitute the mountains of Rougemont, Montanville, and Mount Royal.[2] In the Canary Islands, the exhibition of basaltic and other volcanic products is exceedingly grand. Over marine lavas and tuffs, trachytic and basaltic products of subaerial volcanic origin, between 4000 and 5000 feet in thickness, have been piled, and in the central parts of the Grand Canary reach a height of 6000 feet above the level of the sea.[3]

In India an immense tract is overspread by sheets of basalt, stretching from Bombay to Umurkuntuk, and from Belgaum to Goona. These sheets are associated with freshwater strata and volcanic ashes, and are referred by Mr. Blanford to the Upper Cretaceous epoch.[4]

Art Illustrations. Basalt has been fancifully used in sculpture in ancient times by Egyptians, Greeks, and Romans, and in the galleries of Italy we occasionally meet with illustrations of its application to statuary purposes. Thus in the Museum at Naples,

[1] Jameson, System of Mineralogy, iii. 188.

[2] Logan, Geol. of Canada.

[3] Lyell, Student's Elements of Geology, p. 522.

[4] Mem. Geol. Survey, India, vol. vi. part 2. See also Malcolmson, Geol. Trans. 2 ser. vol. v., with map.

amongst the Egyptian antiquities is the statue of an Egyptian priest in black basalt, and a remarkably truthful figure of a negro, the only human subject for which a basaltic statue appears suited. As applied to the representation of animals it is otherwise, and of its suitability in this direction we have examples in the two water-spouting lions, which repose on either side of the grand central stairs leading up to the Capitol at Rome. They are of black polished basalt with veins of porphyry, and are of Egyptian workmanship.

In the Gallery of the Uffizi, in Florence, there are several illustrations of the use of basalt. One of these is a life-size torso of early Roman workmanship, and a torso of Bacchus in the chamber called 'The Cabinet of the Hermaphrodite'; while small images of Egyptian deities are deposited in the Louvre, at Paris, one of which represents the goddess Paght, and belongs to the eighteenth dynasty.

Melaphyre of a very fine green colour, from Ternuay, Department of Haute Saône, has been employed in the decoration of the tomb of Napoleon I.; and a similar rock with crystals of Labrador felspar, porphyritically developed, is obtained from the quarries of Belfay, near Vésoul, in the same department.

Special uses of Basaltic Rocks. Basalt and dolerite are among the most effective rocks in resisting crush-

ing force. This has been proved by the experiments of Mr. Wilkinson on one-inch cubes of different kinds of stone; 32,130 lb. weight being required to crush a specimen from Moore Quarry, Ballymena, Co. Antrim; this specimen, which was visibly crystalline, seems to have been exceptional, several other cubes having been crushed by weights a little under 1900 lb.[1] Basalt weighs 171–181 lb. per cubic foot absorbs less than 1–4th lb. of water per cubic foot, and is extremely durable. With these qualities, it is admirably adapted for street paving where there is much traffic, for foundation and curb stones, and for road-metal; but, except in very rare cases, and when mixed with light-coloured freestones, its use as a building stone is highly objectionable owing to its gloomy and heavy appearance.

[1] Practical Geology of Ireland, by G. Wilkinson, M.R.I.A. (1845), p. 347 and Table I.

CHAPTER III.

LAVAS.

LAVAS. Under this head are a variety of rocks largely employed for building purposes on the Continent, from the most ancient down to modern times. Such is the case in Central France, the districts of the Lower Rhine, the Moselle, and in Italy—countries where these rocks have been erupted from volcanoes either extinct, or in activity.

These lavas (from which we omit basalt and dolerite, already described) are generally highly silicated, and come under the general terms of trachyte and phonolite, or clinkstone; the latter, however, is rarely the product of modern volcanic activity.[1]

Trachyte. (From τραχὺς, rough.) Spec. grav. 2.4–2.8; contains silica 50.67 per cent. This name was first proposed by Hauy in the year 1822 for certain rocks of Auvergne,[2] and was soon generally adopted for volcanic rocks, having a rough felspathic base formed of sanidine, oligoclase, with accessories such as augite and mica, silica or hornblende. When there are crystals or grains of free quartz, or sani-

[1] B. von Cotta, Eng. edit. p. 182.   [2] Zirkel, Petrog. ii. 141.

dine, it becomes trachyte porphyry, of which there are examples in Cos. Antrim and Down, in Ireland. In the trachyte of the Drachenfels, oligoclase accompanies sanidine as a constituent, with magnesia-mica, and hornblende.[1] The varieties of this rock, consequent on changes in chemical composition, or the presence of accessory minerals, and different rates of cooling from a molten state, are endless; for while on the one extreme, we have a crystalline granular rock,

MAGNIFIED SECTION OF TRACHYTE FROM PUY CAPUCIN (A. V. LASAULX).

resembling granite, on the other we find the same constituents passing into obsidian (or volcanic glass), or pumice-stone so porous as to float on water. In this condition it passes beyond the category of building stones, and requires no further consideration here.

Generally speaking, trachytes are the representatives of the acidic (a highly silicated) class of volcanic rocks, as basalts are of the basic class.

[1] Zirkel, Petrog. ii. 180.

Trachyte is generally of a light grey colour. It occurs in sheets, or thick beds alternating with basalt; or else forming the central cones of volcanoes as in the Auvergne district of France.

Application of Lava to building purposes. Lava has been used as a building material in the volcanic regions of Central France, the districts of the Moselle, and the Lower Rhine, and to some extent in Southern Italy. The lava of Agde (Hérault) produces blocks suitable for large structures, such as bridges and aqueducts; that of Volvic (Puy-de-Dôme) has been used in churches and buildings of Clermont, and other towns in this department, some of which are as old as the tenth century. The lava of Andernach, quarried in large subterranean caverns at Niedermendig, was used in Roman structures at Cologne, Neuvied, &c., as well as in those of more recent date; and is now chiefly worked for millstones, which are held in high estimation, and exported to various parts of Europe and Britain.

Lava has been used in Rome, Naples, and the ancient cities of Southern Italy, chiefly as a paving stone for the streets, from very ancient times. With this stone the Piazza di S. Pietro is chiefly paved; also the recently uncovered Via Sacra of ancient Rome, as well as other streets and squares of the Eternal City. The street pavement of Pompeii, laid down probably a thousand years before the com-

mencement of the Christian era, in large polygonal blocks, excites, and deserves to excite, more wonder than the bright columns, and baths, and fountains, and flesh-coloured frescoes of this once gay and luxurious city.[1] Of the same stone taken from the ancient lava-sheets of Vesuvius are formed the remarkable corn mills, which are amongst the most curious objects of ancient workmanship in Pompeii.[2]

[1] See a drawing of this pavement in Professor Phillips' 'Vesuvius,' p. 32.

[2] These were in the form of a double egg-cup, capable of rotating on a conical pedestal, and turned by hand spikes. The upper cup received the grain which was ground in the lower.

PART V.

SERPENTINOUS ROCKS.

CHAPTER I.

SERPENTINE.

Sp. gr. 2.5–2.7. Contains silica 38.49–44.22 per cent.

Of all the stones used for decorative purposes in architecture, none surpass in general estimation some of the varieties of serpentine. This is due both to the richness and variety of its colouring, and its capability of receiving a fine polish. It is not, however, adapted to outdoor use, especially in the smoky or gaseous atmosphere of cities; for, being acted on by hydrochloric and sulphuric acids, it is liable either to decay, or to become tarnished on the surface. But, for indoor decorations, and the construction of slender shafts, pilasters, pedestals, vases, inlaid slabs for walls, and ornaments of various kinds, serpentine is often employed with successful results.

Mineralogists have separated this rock into the following varieties:—1. *Precious*, or *noble serpentine*, comprising the purer translucent and massive varieties, with a rich oil-green colour. 2. *Common*

serpentine, or the opaque varieties forming rock masses, like those of the Lizard, Portsoy, Anglesea, and Zöblitz. 3. *Fibrous serpentine*, including baltimorite, crysotile, metaxite, picrolite. 4. *Foliated serpentine*, comprising antigorite, marmolite,[1] &c. To the above might be added eozonal serpentine; and loganite, of Dr. Sterry Hunt.

Composition and Origin. Pure serpentine is a hydrated silicate of magnesia; but as a rock it is generally mixed or interlaced with carbonate of lime, diallage, dolomite, steatite, and other foreign substances. Its origin by a process of metamorphism, or transmutation, from dolomite, diorite, hornblende rock, and gabbro,[2] is now generally recognised, though formerly it was regarded as a product of igneous fusion.[3] Breithaupt first detected serpentine under the crystalline form of hornblende, and

[1] Bristow, Glossary of Mineralogy (1861).

[2] This view of transmutation from igneous rocks probably offers a sufficient explanation of the phenomena exhibited by the serpentine of the Lizard in Cornwall and other districts, where it has the appearance of an erupted mass in relation to the surrounding rocks. Those who are interested in this subject should make themselves acquainted with the experiments and observations of Mr. A. Gages, M.R.I.A., published in Reports to the British Association, entitled 'Special Researches on the formation of Minerals,' 1862 and 1863.

[3] That this was the opinion of so eminent an observer as Sir H. De la Beche in 1839 will be seen by reference to his work on Devon and Cornwall, p. 30. This opinion was probably afterwards modified.

remarked,[1] that probably some beds of serpentine were originally hornblende rock, or diorite. This has since been fully established; while serpentine itself, on the other hand, can be transmuted into chlorite and talcose schist. The presence of serpentine almost exclusively amongst that class of rocks known as metamorphic, is, amongst other phenomena, in favour of the more modern view. B. von Cotta even questions whether serpentine exists as an original and independent mineral, as the crystals with amorphous fracture, which some mineralogists call serpentine, according to others are only pseudomorphs of crysolite, or some other mineral.[2] Bischof and G. Rose also share this view, and have shewn that serpentine may originate by alteration from the most diverse rocks and minerals.[3]

M. Delesse has shewn that the variations of colour in serpentine are in a great measure due to the proportion and degree of oxidization of the iron which it contains;[4] a deduction which may be illustrated by a comparison of the analyses of the deep red varieties from the Lizard in Cornwall with those of some other districts of a generally greenish hue. The following will serve for examples of the chemical composition of this rock.

[1] Neues Jahrb. p. 283. [2] Von Cotta, Rocks, Eng. ver. 314.
[3] Chron. and Phys. Geol., Eng. ver. ii. 417.
[4] Zirkel, Petrog. i. 320.

	I. Red, Kynance Bay Cornwall (1).		II. Light Green, Galway (2).		III. Dark Green, Col de Pertuis, Vosges (3).		IV. Green Homogeneous, Oxford, Canada (4).
Silica	38.29	....	40.12	....	40.83	....	40.30
Alumina	—	....	2.00	....	0.92	...	—
Protox. Iron	13.50	....	3.47	....	7.39	....	7.02
Oxide Manganese.	—	....	—	....	trace	....	0.26
Oxide of Chromium	—	....	—	....	0.68	....	trace
Lime	—	....	—	....	1.50	....	—
Magnesia........	34.24	....	40.04	....	37.98	....	59.07
Water, &c.	12.09	....	13.36	...	10.70	....	13.35
	98.12		98.99		100.00		100.00

(1) Haughton, Phil. Mag. x. 253. (2) Bristow, Glos. Mineral. (3) Delesse. Ann. des Mines, xviii. 341. (4) Hunt, Amer. Journ. Sci. xxv. 219.

ENGLAND AND WALES—*The Lizard, Cornwall.* The serpentine of this district has come into great and just repute within the last thirty years. It forms a large tract of the Lizard promontory, and is associated with diallage rock and hornblende schist. Its relations to these rocks are somewhat obscure, notwithstanding the careful investigations of Sir H. T. De la Beche.[1] In some places the hornblende rock appears to graduate upwards into the serpentine; in others, masses of serpentine appear to have been intruded amongst the hornblende rock. It is probable, however, that all these phenomena may be accounted for by considerations connected with the intensity of the metamorphism to which the rocks of the district have been subjected.

The serpentine of the Lizard is extremely variable in colour. The principal mass, like that of some other

[1] Geology of Cornwall, Devon, and Somerset, p. 30 (1839).

districts, is of a deep olive-green, but this is variegated by veins or bands and blotches of rich brownish-red, or blood-red, mixed with lighter tints. This variety may be obtained at the Balk, near Landewednack, at Kynance Cove, at the Signal-staff Hill, near Cadgwith, at Cennack Cove, St. Keverne, and on Goonhilly Downs.[1] A variety with an olive-green base, striped with greenish-blue steatite veins, is found near Trelowarren; and a third and especially beautiful variety, at Maen Midgee, Kerwith Sands, in which the deep reddish-brown base is studded with crystals of diallage, which shine out with a metallic lustre from a polished surface.[2] Describing this stone, Mr. R. Hunt says—'For purposes of ornament this elegant stone is well adapted, being moderately soft, but not brittle, and therefore easily worked, while it is sufficiently hard to receive an excellent polish. It was formerly thought that blocks of a large size could not be obtained; quarries have, however, been opened, and it is found that the size and solidity of the blocks increase with the depth from the surface. There are few spots around the British coast more beautiful and grand than Kynance Cove, where the serpentine rock, in all its varied dyes, is

[1] Geology of Cornwall, Devon, and Somerset, p. 499.

[2] Another variety has veins of white steatite traversing a base of a reddish brown colour, of which specimens may be seen in the Museum of Practical Geology, London.

polished by the beat of the Atlantic waves, and in contrast with the white sands of the shore, is rendered still more striking and characteristic.[1]

Lizard serpentine is now much used in some modern churches, for ornamental fonts, pulpits, and small shafts and pilasters, as well as for vases, tazze, and slabs for inlaid work.[2] Blocks 7 to 8 feet long and 2 to 3 feet in diameter have been obtained from the quarries.[3]

Anglesea. Greenish serpentine, sometimes slightly reddish, occurs amongst the metamorphic schists of Anglesea, at Llanfechell and Ceryg-moelion. A brecciated, serpentinous marble, with veins of white calc-spar, is found at Tre-gala, near Llanfechell.

IRELAND. The serpentine of West Galway, called 'Connemara marble,' is justly prized as an ornamental stone. It occurs in irregular beds, amongst the metamorphic schists and quartzites, which are regarded by Sir Roderick Murchison to be of Lower Silurian age.[4] There are two varieties of the serpentine: one from Letterfrack is of a dense, opaque, and uniformly deep green colour, and appears to be derived by a metamorphic process from horn-

[1] Descrip. Guide Mus. Prac. Geol. 3rd edit. p. 21.

[2] In the Museum of Practical Geology there is a tazza of reddish serpentine, the shaft of which is entwined by a dolphin of green steatitic serpentine, both from the Lizard, and made by Mr. Pearce, of Truro.

[3] Gwilt, Encyc. Arch. edit. 1867, p. 497.

[4] Siluria, 3rd edit.

blende rock; but the more beautiful and highly prized variety is due to transmutation from dolomitic limestone. This variety occurs in the form of bands and laminæ, often twisted and tangled, of varying shades of green, from deep sap-green to translucent pale yellowish-green, and interlaced with bands of white calcite, or crystalline dolomite. Sometimes speckled or mottled varieties, exhibiting a *quasi* 'eozonal' structure, occur. The principal quarries are at Lissoughter Hill, Recess, Ballynahinch, and at Streamstown, between Clifden and Letterfrack.[1]

When used with discretion, and sparingly, amongst light masonry, this stone is displayed to the best advantage; but the effect of a large surface devoid of other materials for the sake of contrast, is not pleasing to the eye; nor does it withstand the influence of a smoky or gaseous atmosphere. The effect both of the internal and external use of the Connemara marble is well shown in the new Museum of Trinity College, Dublin.[2]

Co. Donegal. Foliated green serpentine, with bands of calcite, or dolomite, occurs at Crohy Head; and a denser, olive-green variety, is found at Ang-

[1] Specimens may be seen in the hall and galleries of the Royal College of Science, Dublin.

[2] Small tablets let into the outside wall of the Museum have become tarnished within the space of ten years. Within, the columns which adorn the hall of the building have retained their polish.

hadovey, of which there are specimens in the Museum of Trinity College, Dublin.

Co. Sligo produces serpentine of a deep leek-green colour, which has been obtained from Rock Wood Glen, west of Lough Gill;[1] and in Co. Donegal, serpentine with garnet rock is found at Anghadovey.[2]

SCOTLAND—*Portsoy, Banffshire.* The serpentine of this locality is very rich and varied in colour; it passes from sap-green to deep red, and is variegated with veins of white steatite. It does not appear to be as largely in request as it deserves. Specimens and worked ornaments of this stone may be seen in the Museum of Practical Geology.[3] Serpentine also occurs in the Alie Hills, Aberdeenshire; Killin, Perthshire; and in the Shetland Islands of Unst and Fetlar,[4] where it contains chromic iron.

[1] A specimen of which is in the collection of the Royal College of Science, Dublin.

[2] Brit. Assoc. Report, 1863, p. 54.

[3] In the Hall, No. 183, a cube; 184, obelisk.

[4] Hunt, Descrip. Guide M. P. G. p. 22.

CHAPTER II.

SERPENTINE OF THE CONTINENT.

SERPENTINE is distributed extensively in some parts of Europe, associated with crystalline rocks; amongst which the following may be mentioned:—

Saxony, at Waldheim and Greifendorf, with garnets; and at Zöblitz.

Moravia, at Hrubschitz, with chromic iron; Silesia from the Reichenstein.

The Vosges Mountains. The serpentine of the Vosges, at Epinal, frequently contains garnets of various colours, from blood-red to green; diallage, magnetic iron, and green olivine, also occur as accessories.[1] It is traversed by dykes of noble serpentine, and both contain chromic iron-ore. The diversity of colour indicates differences in the amount of chromium.[2]

The Alps. Serpentine occurs amongst the rocks of the Matterhorn, the Breithorn, and the Alpe la Mussa in Piedmont, &c.[3] The crystalline schists, both of the Swiss and Italian Alps, in the cantons of

[1] Delesse, Ann. des Mines, xiv. 78.

[2] Bischof, Chem. and Phys. Geol., Eng. ver. ii. 438.

[3] Zirkel, Petrog. i. 321.

the Grisons and Wallis (The Valleys), are productive of thick masses of serpentinous rocks.[1] They are also found in the Sierra Nevada, in Spain.[2]

France (Hautes Alpes). *Serpentine of Saint Véran, and of Maurins.* This is one of the handsomest varieties, and has been quarried since 1851. It is an ophicalcite, or breccia of serpentine, imbedded in carbonate of lime, of a light green colour. The stone is delivered in Paris, and employed for decorative purposes.[3]

Serpentine also occurs at Pech-Cardaillac, at Véru and Estival, near Saint Céré, in the department of the Hautes Alpes; at Arvieu, Canton de Cassagnes (Aveyron); in the Zermatt Valley, in Switzerland; and at Bivinco, near Bastia in Corsica.[4]

Italy. This country is rich in serpentinous rocks, as in other varieties of marbles, which are largely used in the internal decoration of the churches, mansions, and public buildings. An account of these was originally drawn up, with great ability, by M. Rondelet,[5] and more recently by M. Delesse,[6] for the Exhibition of 1855. The chief sources of serpentines are Susa, in the Alps of Piedmont; Val Sezia, Val di Pegli, Pietra Lavezzara, near Genoa; and Prato, near Florence. The serpentine known as *vert antique*

[1] Zirkel, Petrog. i. 328.
[2] Chateau, ii. 456.
[3] Chateau, ii. 506.
[4] *Ibid.* ii. 456.
[5] Traité de l'art de bâtir.
[6] Les matériaux de construction.

(verde antico), s probably of no special description, but the name applies to many varieties of green serpentinous rock used by the ancient Romans, sometimes brecciated, or variously veined, and derived from various sources, both those of Italy, Greece, and Egypt.[1] These ornamental stones, extracted from the ruins of buried cities, have been re-cut and polished, and are now used in the internal decorations of modern buildings. I shall now give a short account of the more remarkable varieties.

Serpentine of Prato (Verde di Prato). This beautiful stone is quarried amongst the Apennines a few miles from Florence, and is largely used in Tuscany. It is a spotted deep green serpentine, or ophite, with strings of white steatite (or noble serpentine, according to Delesse) ramifying through it. It takes a fine polish, but on exposure to the atmosphere is subject to rapid decay, as is evident by an examination of the walls of the Cathedral of Florence. In this building, as well as in the campanile commenced by Giotto in 1334, and the church of S. Maria Novella (1456), alternating courses of white marble from Carrara, serpentine of Prato, and reddish sandstone, have been introduced with great effect, and combine to produce one of the most richly

[1] For example, the four columns of verde antico in the Cabinet of Gems, Galleria degli Uffizi, in Florence, differ much from one another in the structure of the material.

decorated exterior walls of any edifice in existence. New courses of stone are now being used with great judgment in replacing those which have been decayed.

Genoa (Verde di Genova). At Pietra Lavezzara, an ophicalcite has been quarried from time immemorial, and has been much used in France under the name of 'Vert de Gênes.' It is a brecciated rock consisting of fragments of green, dark green, and in some places, brown or red colours, cemented by white or light-green calc-spar.[1]

Verde di Pegli. In the neighbourhood of Genoa is another handsome serpentinous rock, known by the above name, and found along the course of the torrent Varenna.[2] It is also brecciated, composed of fragments of deep-green serpentine disseminated in a cement of light-green calc-spar which forms the greater part of the material; the contrast between the rich green of the one kind of stone and the light green of the other being very agreeable to the eye.

Euphotide, a dense serpentine with crystals of diallage and felspar, along with ophicalcite, is found at Matarana near Genoa, and at Beverone (*Massa and Carrara*) of varied colouring.[3]

Greece. The serpentine of Tenos is an ophicalcite of a bright green colour, traversed by veins of white

[1] Chateau, ii. 552. [2] *Ibid.*

[3] Mr. W. P. Jervis, Mineral Resources of Italy, 1862.

or greenish calc-spar; crystalline grains of oxide of iron and iron-pyrites sometimes occur. The rock resembles the ophicalcite of Maurins in the Hautes Alpes.[1]

Egypt. Serpentine was worked in ancient times in Upper Egypt, and along the road from Keneh to Kosseir (Pierre de Baram). It was employed by the ancient Egyptians,[2] and specimens brought from Egypt may probably be observed in Italy at the present day.

Spain. In the Sierra Nevada serpentine of a deep green colour, with crystals of diallage of a bright green, is obtained; and at Saint-Jean, in the same range, an ophicalcite which was used by the Moors in the decoration of the Alhambra, and is of a kind almost peculiar to Spain, and called by Chateau 'ophicalce pétrosiliceuse.'[3]

Ural Mountains. Serpentine is developed in huge masses amongst the crystalline and metamorphosed Silurian rocks of the Uralian Mountains throughout a large extent of their range from north to south.[4] Amongst other localities it is found not far from Miask, containing schillerspar and bronzite;[5] near Kytschimsk containing gold;[6] also near Katherinenburg, Tschaikowski, 20 fathoms (120 feet) in

[1] Delesse, quoted by Chateau, ii. 561.
[2] *Ibid.* [3] *Ibid.* ii. 565.
[4] Murchison, Siluria, 4th edit. 452, 14.
[5] G. Rose, Journ. in the Ural, ii. 164. [6] *Ibid.*

thickness, associated with chlorite schist. According to the observations of G. Rose, serpentine rocks are found in the North Ural at Kuschwinsk and Turinsk; in Mid-Ural, at Katherinenburg and Newjansk; and in South-Ural near Miask and Kytschimsk. Their specialities at some of these places have already been noticed.

India. Serpentine occurs amongst the great metamorphic beds of schist of Southern India, and amongst other places is worked for useful purposes in the Midapoor district and amongst the Neilgherry Hills.[1]

[1] Mr. H. F. Blanford, Mem. Geol. Survey of India, i. 276.

CHAPTER III.

SERPENTINES OF THE AMERICAN CONTINENT.

Canada. The serpentine rocks of Canada are found amongst the metamorphic strata of the Laurentian series, and the Quebec group. From the former they have been obtained at Wentworth; also from the 5th range of Grenville and Burgess, where the green colour is varied by rich brown clouds and spots, and is highly ornamental.[1]

The Laurentian serpentine has recently attracted much investigation from the views put forth by Sir W. Logan, Dr. Dawson, Dr. Carpenter, and others, regarding the organic structure of this rock—views, however, which are combated by Professors King and Rowney, of Queen's College, Galway. The question is one of much uncertainty, and must be left to the determination of those who, possessing an intimate acquaintance with the structure and mode of development of lowly-organized marine forms on the one hand, and of serpentinous minerals on the other, have had opportunities of microscopic examination of the rocks themselves. Therefore, without

[1] Logan, Geology of Canada, p. 471 (1863).

offering any opinion on this question of structural affinity, I only venture to state that, as all great masses of marine limestone, even from the earliest geological ages, must be regarded as of organic origin, it is not improbable that some traces of their structure may have been retained, even in rocks which have undergone some amount of metamorphism, such as the eozonal serpentines of Canada.

A fine block of this serpentine with polished surface, is now in the gallery of the Museum of Practical Geology, London.

In the Quebec group, serpentinous rocks are still more abundant, of darker colour, tougher, and better suited for ornamental purposes. They seem to be the product of metamorphism from dolomites, and are widely distributed in Eastern Canada, as at Melbourne, Orford, Saint Joseph, Mount Albert, and Stukely. The serpentines of Roxbury, and Cavendish at Vermont, resemble those of Italy, and are largely employed for ornamental purposes.[1]

Newfoundland. A mountain between 2000 and 3000 feet in height, composed of serpentine, rises near South Arm, in a district formed of metamorphic rocks.[2]

United States. Good serpentine is found at Phillipstown, Port Henry, Gouverneur, and Warwick in N.Y., Newburyport, Westfield, and Blanford, in Mass.; at

[1] Logan, Geology of Canada, p. 821. [2] *Ibid.* p. 820.

Kellyvale and New Fane, Vt.; Deer Island, Maine; New Haven, Conn.; and Bare Hills, Md. Marmolite (foliated serpentine) at Bodoken, N.J., and Blanford, Mass. The quarries of Milford and New Haven, Ct., afford a beautiful *verde antique.*[1]

[1] Dana, Manual of Mineralogy, edit. 1870, pp. 146–7.

PART VI.

CHAPTER I.

MARBLE.

Körniger Kalk, Marmor (*Germ.*) Calcaire saccharoide, Marbre (*Fr.*)
Spec. grav., 2.6–2.8.

THE true marbles are crystalline limestones capable of receiving a polish. They are exceedingly various in colour, pattern, and structure, owing to the intermixture of foreign or accidental substances, and their mode of formation. They also vary much in hardness and durability, and in the degree of crystallization.

Marbles under some form are found amongst all great limestone formations. It would, therefore, be impossible to describe them in any degree of detail; and I must content myself with some account of the more valuable kinds in use in ancient and modern times, both in this country and the Continent. These we shall discuss under the two general heads of ornamental and statuary marble.

These rocks are amongst the most beautiful pro-

ductions of nature; nor can they be reproduced by art. It is in vain that we attempt to portray the rich and ever-varying hues of the coloured varieties; much less can we produce those colourless kinds in which the artist embodies his conceptions of grace and beauty. Attempts, indeed, have been made with a wonderful degree of success[1] to produce exact copies in cement and colour of the richer varieties; but in a short time the eye is undeceived, and we discover that the rich decorations are but superficial, and extend not beneath the surface. Indeed, I am inclined to agree with Mr. Ruskin, that the art of merely copying what Nature yields spontaneously is an ignoble one, as it forbids the use of the higher faculties of imagination and invention.[2] While the accessible portion of the earth's crust is profusely stored with every variety of stone which we can desire for purposes of art or decoration, it is ignoble to have recourse to deception and artifice in order to supply our wants.

Marbles of Great Britain. While white statuary marble is absent from Great Britain, this country is

[1] The author was once consulted by a lady, who proposed to decorate the walls of the entrance hall of her country house with slabs of imitation malachite! She was recommended to make use of some less costly and more commonplace variety of marble, as no one would be deceived by the imitation in malachite.

[2] 'There is not a meaner occupation for the human mind than the imitation of the stains and striæ of marble and wood.'—*Stones of Venice*, III. i. 46.

well supplied with coloured varieties, derived from the Devonian, Carboniferous, Purbeck, and Wealden formations. We shall now describe them, beginning with the oldest.

Devonian Marbles. The marbles of the formation which derives its name from Devonshire[1] are worked at Plymouth; Pitit Tor, near St. Mary's Church, Babbacombe; and Newton Bushell. They are sometimes coralline, yielding 'madrepore marbles,' and the prevalent tints are various shades of grey, with veins of white or yellow; while red varieties are also found in smaller quantities. At Ipplepen, and the vicinity of Totness, there is a reddish variety that is extremely handsome; and at Kitley Park there is a green marble, and rose-coloured dolomite, both of which are considered by Sir H. De la Beche as possessing much beauty, and well adapted for ornament or use.[2] From Barton's quarry at Ipplepen, blocks eighteen feet square are now conveyed to London.

This quarry supplied the monolithic polished shafts for the forty columns (eighteen out of one block), each 12 feet 3 inches in length, and 18.5 inches in diameter on the fillet, for the new building of the National Provincial Bank of England, in Bishopsgate Street. The bases are of Irish black marble, and the capitals of cream-coloured Huddlestone stone.

[1] First proposed by Sedgwick and Murchison, in 1836.

[2] Geol. Report, Devon, &c., p. 498.

In the corridor of the New Freemasons' Hall are four columns, two being from the Barton's quarries, and two of Languedoc marble. Eight others are placed in the coffee-room of the Charing Cross Hotel.[1]

The quarries at Oreston, near Plymouth, furnished the stone originally employed in the construction of the Plymouth Breakwater; and in connection with the use of limestone for that purpose, one curious circumstance attracted attention. Between high and low water, the boring molluscs (*Pholas dactylus*) so perforated the limestone, that it was thought necessary to replace the blocks by granite, which effectually resists the boring operations of these animals.[2]

The North Devon marbles are also abundant and diversified. There are varieties of black and white from Bridestow, South Tawton, and Drewsteigton. Some from Chudley, Staverton, and Berry Pomeroy have a black ground, with large veins of calcareous spar traversing it in all directions.[3]

The Devonshire marbles are now largely used for chimney-pieces, pilasters, columns, and inlaid slabs.

Purbeck and Sussex Marbles. These two kinds of marble are both of fresh-water origin, and are derived from the Purbeck and Wealden formations which lie on the confines of the Oolitic and Cretaceous

[1] Gwilt, Encyc. Arch. p. 492.
[2] R. Hunt, Descrip. Guide M. P. G., p. 24.
[3] Gwilt, Encyc. Arch. p. 492.

systems of rocks. They are similar in appearance, and are composed of numerous shells of calcareous spar, embedded in a dark blue, or greyish compact limestone, which takes a good polish. The shells belong chiefly to the genus *Paludina*, but the species characterizing the Sussex stone is larger than that of the Purbeck (*P. Carinifera*).

The Purbeck marble has been chiefly derived from Durdlestone Bay, near Swanage, in Dorsetshire. It occurs in thin beds, in the upper division of the fresh-water series; and has been largely employed for slender shafts and columns, as well as for sepulchral monuments in cathedrals and churches of the South of England, from the twelfth to the sixteenth centuries. Mr. Bristow states that the marble formerly used, and procured from quarries now exhausted, near Swanage, has sometimes a pinkish tint, but frequently weathers badly. The stone now raised from other parts of the same district is of superior quality.[1] Instances of the use of this stone may be seen in Westminster Abbey; the Temple Church, London; the tomb of William Rufus in Winchester Cathedral; and the shafts in Lincoln Cathedral.

The Sussex marble from Kent and Sussex occurs in beds seldom exceeding a foot in thickness. Like the Purbeck stone, it has also been largely employed in ecclesiastical buildings, for slender shafts to support

[1] Descrip. Catal. Rocks M. P. G. p. 69.

the *triforia* or upper arcades of cathedral churches, as at Canterbury and Chichester. The episcopal chair of Canterbury is also formed of it.[1]

Both these varieties of marble have now generally fallen into disuse, being inferior, both in richness of colouring and durability, to the more ancient and crystalline marbles of the British Isles.[2] Nor can we regard this recent want of appreciation with regret, as the cold grey tints these stones present are ill suited to contrast effectively with the building stone of the interior of our public edifices.

Derbyshire. The marbles of Derbyshire are all derived from the Carboniferous limestone. In colour they vary from black, blue, and light grey to russet; they are also distinguished by peculiarities of structure, chiefly depending on the organic remains which they contain, so that we have the 'bird's eye,' 'dog's tooth' or 'mussel,' 'entrochal,' 'shelly,' and 'brecciated' varieties.[3] Quarries of black marble are situated near Ashford, where machinery for cutting and polishing the blocks was first used in 1748.[4] These various kinds of marble, including the 'rosewood' variety, are principally used for inlaying

[1] Dr. Mantell, Geol. South-East of Eng. p. 184.

[2] The large columns supporting the clerestory in Westminster Abbey have now scarcely a trace of their original surface left. (C. H. Smith, Trans. Inst. Brit. Arch. 1853.)

[3] Gwilt, Encyc. Arch. p. 492.

[4] *Ibid.*

work, and for vases, tables, and miniature obelisks. But chimney-pieces, columns, &c., are now made at Ashford, Bakewell, Allport, Buckland Hollow, and at Derby. The imitations of 'Florentine work,' or Mosaic, are remarkable for beauty of design and fineness of execution.[1]

Anglesea. A beautiful marble, apparently formed by a combination of crystalline limestone and serpentine, called *Mona marble,* is obtained in Anglesea. Its colours are dark green, leek green, and sometimes purple, irregularly blended with white.[2]

Isle of Man. The following is Gwilt's account of these marbles. (1) Black flagstone from Poolwash, worked for upwards of 200 years, and which is used in the steps of St. Paul's Cathedral; presented by Bishop Thomas Wilson. (2) Grey shelly and encrinital marble, from Poolwash. (3) Black, extremely hard and durable, and taking a good polish, from Port St. Mary. (4) Pale marble, from Scarlett. Of this durable stone Castle Rushen, 900 years old, is built. These marbles are derived from the Carboniferous limestone which occupies a small district at the southern extremity of the island.

Ireland. The Carboniferous limestone districts of

[1] Gwilt, Encyc. Arch. p. 492.

[2] *Ibid.* Grey marble is also quarried at Kendal, in Cumberland.

Ireland produce a variety of marbles well suited for decorative work.[1]

Black Marble. The principal quarries of black marble are those at Kilkenny and Galway. The Kilkenny marble takes a beautiful polish, and when first cut is quite black; but the organic matter to which its blackness is due, gradually passes off, and ultimately white marks of fossil forms present themselves upon its surface. The Galway quarries are situated at Angliham and Menlough, along the verge of Lough Corrib, and blocks are largely exported.[2] Blocks of twelve to fourteen feet long, and four to five feet wide, and about twelve or thirteen inches in thickness, can be raised. Some large slabs sixteen feet long were raised some years since, and worked in London into landing-steps, and carved balustrades for Hamilton Palace in Scotland.

Black marble is also found at Churchtown and Doneraile, Co. Cork; Carlow; and black and white varieties near Tralee, and in the Islands of Kenmare River.

[1] Much of my information of the Irish marbles is taken from Kane's Industrial Resources of Ireland (1844), 231–3, and Wilkinson's Practical Geology, &c., 1845. Specimens of these marbles, both in the rough and worked states may be seen in the hall and galleries of the Royal College of Science, Dublin. In this city there are extensive marble cutting and polishing works, which will amply repay a visit.

[2] Mr. Kinahan gives a full account of these quarries in Expl. Memoir to sheet 105 of the Geological Survey Maps, p. 21.

Grey Marbles are obtained from Ballykiloboy quarries, five miles from Waterford; at Tullamore, and Clonmacnoise, King's County, in company with dove-coloured varieties; also at Dromineer, Tipperary; Carrigaline, and Castlemary. They are often encrinital. From Moate, Co. Meath, a handsome dark grey marble variegated with corallines is obtained.

Reddish and Variegated Marbles are found near the city of Armagh, and at Middleton, Churchtown, and Little Island Quarries, Co. Cork. The Armagh stone presents when polished varying tints of light red, passing into purple, yellowish-brown, and dove-colour; that from Middleton and Churchtown is of a rich brownish-red, variegated with white or light-coloured strings, specks and patches; and very handsome chimney-pieces, panels, pilasters, and slender shafts for buildings have been formed of it. A brownish-red variety, mottled with various shades, occurs at Ballymahon, Co. Longford. At Pallaskenry, in the Co. Limerick, a dark red and mottled marble is met with, and has been largely used.[1]

Cream-coloured Marble is obtained from Armagh and Cheevy, six miles from Dungannon.

Variegated Marbles. At Killarney occurs a very beautifully striped white and red marble, and in the islands of the Kenmare River, near Dunkerron, marbles of various colours, black and white, purple,

[1] Gwilt, Encyc. Arch. p. 495.

white and yellow, and some specimens of a purple colour, veined with dark green, resembling bloodstone.[1] 'Sienna' marble is obtained from several places in King's County; but the best veined and mottled Sienna is found near Shannon Harbour, on the Galway side. It is susceptible of a high polish, and exhibits bright and distinct colours.[2]

In Donegal the bands of limestone are converted into crystalline marble when in proximity to the granite.[3] It is as yet uncertain whether any of this white marble is sufficiently homogeneous and pure for statuary purposes; but promising specimens have been obtained from Ardes.

Scotland. An interesting variety of marble occurs at Tiree, in the Hebrides, where it is associated with Laurentian gneiss. It consists of a base of pink limestone, through which are disseminated crystals of dark green augite, (?) giving the stone a porphyritic appearance.[4] The following are noted by Gwilt.[5] The *Iona marble*, whose colours are grey and white, sometimes mixed with yellowish spots or

[1] Kane, Ind. Res. of Ireland, p. 232.

[2] None of these so-called 'Sienna marbles' are equal in richness to the Italian variety.

[3] Report on the Granites of Donegal, by Messrs. Scott, Griffith and Haughton. Brit. Assoc. Rep. 1863.

[4] R. Hunt, Descrip. Guide M. P. G. p. 26. The bust of Sir H. T. De la Beche, in the Library of the Museum of Practical Geology, is supported on a block of this marble.

[5] Encyc. Arch. p. 494.

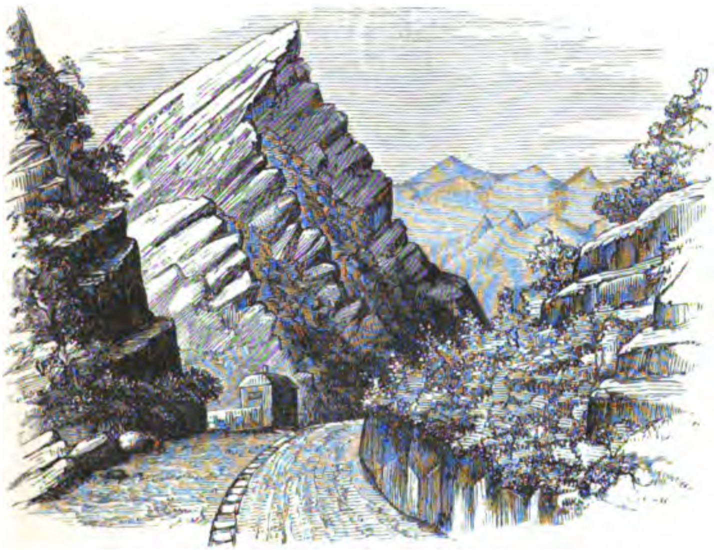
veins of steatite called 'Icolmkill pebbles;' it does not take a high polish.[1] The *Skye marble;* of greyish hue, veined; the Assynt varieties of grey, blue, and dove-colour; Glen Tilt marble, white and grey, with occasional yellow and green spots. Marble of Balliculish, grey and white; that of the Boyne (Aboyne?) grey and white; of Blairgowrie, white; fit, it is said, for statuary purposes.[2]

[1] A specimen of crystalline white marble from Iona with a schistose structure is placed in the Museum of Trinity College, Dublin.

[2] Gwilt, Encyc. Arch. p. 494.

CHAPTER II.

CONTINENTAL MARBLES.



APPROACH TO CARRARA QUARRIES.

Spain, Italy, Sicily, and Greece are the countries of all others the most rich in marbles, both for statuary and ornamental purposes; and it is to Italy that sculptors still have recourse for that pure white

crystalline marble which alone is adapted for the higher kinds of sculpture.

Italy. The most valuable of all the marbles of Italy are those derived from the range of the Apennines overlooking the beautiful bay of La Spezia, in the vicinity of Carrara, Massa, and Serravezza. These quarries supply white statuary marble to nearly all parts of the world, including Germany, France, Britain, and America, besides enormous quantities of white-veined, and variegated kinds for architectural and more ordinary purposes.

The part of the Apennines which contain these quarries is highly picturesque. The central ridges of pale crystalline limestone and schist, with serried outline, rise to elevations of 4000 or 5000 feet, their flanks scored by torrents, and intersected by deep gorges; and these are bounded by less elevated eminences clothed with olive-groves, vineyards, and forest-trees up to their summits. From the base of the hills, a richly-cultivated alluvial plain, evidently an ancient sea-beach, stretches to the sea, and forms a level course for the strada ferrata, by which the blocks of marble are conveyed away to their various destinations, or to ports for shipping. The best quarries are opened along both sides of a deep valley in which the village of Carrara is situated, and along which flows the Torano. In general, the marble has a light bluish hue, or is white with bluish veins;

such kinds being generally sawn into slabs at the numerous cutting and polishing mills situated along the course of the stream. The purer varieties, which are perfectly white, crystalline, and free from flaws, are quarried in blocks, sometimes ten, twelve, or fourteen feet in length, for statuary purposes, and drawn on strong waggons by teams of bullocks down to the railway station at Carrara, whence they are sent to their various destinations. The town of Carrara itself, however, contains several studios of sculptors, who fashion the stone at the spot where it is quarried.

An examination of the marble-beds, and their associated schistose strata, shows at once that their crystalline structure is the result of metamorphism. They are referable to the Liassic and Oolitic, or Jurassic series, as determined by Professor Pilla,[1] who showed that the dark grey limestones of the Valley of Tecchia, containing Jurassic fossils, graduates by changes of colour and crystallization into the pure white of Carrara and Massa; a conclusion, in which Sir R. I. Murchison, who made a detailed examination of the whole chain of the Apennines, has fully concurred.[2]

[1] Bull. Soc. Géol. de France, iv. 1068. Sir H. De la Beche suggested this view several years previously to Professor Pilla's determination. Proc. Geol. Soc. Lond. i. 164.

[2] A very graphic description of the geological structure of the Etrurian Apennines is to be found in Murchison's paper on the Geology of the Alps, Apennines, &c. Journ. Geol. Soc. Lond., vol. v.

Between the two great beds of crystalline limestone worked in the valley of the Torano, are calcareous schists, passing into mica schist; and the impression I received, upon a rather rapid survey in 1871, was that the two great beds of marble are disconnected portions of the same mass on opposite sides of a sharp anticlinal fold shown in these schists.[1] The quarries at Massa produce blocks of white marble rivalling those of Carrara.

These quarries are supposed to have been discovered about 100 years A.C., and they were largely worked in the time of Augustus, who is called by Livy 'templorum omnium conditor ac restituor,' as he transformed Rome from a town of brick to a city of marble. It is certain, indeed, that the quarries of Fantiscritti, situated about three miles from Carrara, were opened by the ancient Romans, from the works of Roman art which have been discovered in them; amongst others, a relief of Jupiter with Bacchus.[2]

The white marble of Carrara has been used for decorative purposes, in many of the churches and public buildings of Italy.[3] Under a smokeless atmo-

[1] The mica schist was originally shale, the calcareous schist earthy limestone, while the crystalline marble was an ordinary Jurassic limestone. Their present condition is due to the subsequent metamorphic action.

[2] Bædiker's Italy, i. 264.

[3] Also in the exterior walls of the Duomo and Campanile of Florence of the thirteenth century, in combination with dark

sphere it is capable of resisting decay for lengthened periods, though it becomes discoloured. Much, however, depends on the proper selection of the stone in the quarry itself.

For statuary purposes, it is admirably adapted; and, although held in less esteem than Parian and Pentellic marbles, it has formed the material out of which have been fashioned some of the noblest creations which the intellect has designed, and hand of man produced. Of these, the Apollo Belvedere, in the Vatican collection, is considered the finest example taken from ancient art; while, in more modern times, Carrara has produced the blocks out of which Michael Angelo and Canova have chiselled their immortal works.

Amongst the monuments of ancient Rome, we recognise this material in a state of wonderful preservation. It is probable that the column of the Emperor Aurelius, if not that of Trajan, both covered with sculptured figures; the triumphal arches of Titus, of Septimus Severus, and of Constantine, all more or less well preserved; and some of the columns which belonged to the temples round the Forum Romanum, are of stone taken from the quarries of the Northern Apennines.[1]

green serpentine (Verde di Cesto) and reddish sandstone, recently introduced.

[1] Not, however, including the three beautiful Corinthian columns

An analysis of this marble, by Wittstein, gave the following results:—Carb. lime, 99.24, carb. mag. 0.28, and oxide of iron, 0.29. It is known, however, that the quality and composition varies considerably, and that varieties differing both in texture and colour may be obtained from the district itself. Small crystals of quartz, and of iron pyrites, occasionally occur, much to the annoyance of the sculptor.

The perishable nature of the marble when exposed to the smoky atmosphere of a British city, is evinced by the decayed state of the tomb of Chantrey, erected in 1820, in the 'God's acre' belonging to St. John's Wood Chapel.

Island of Elba. White lamellar marble occurs at Cape Ortano, and was opened up by the Emperor Napoleon I. when an exile there, but after his departure the quarry was neglected.

Besides the white and statuary marbles, there are other kinds obtained in the vicinity of Carrara, such as the 'Italian-veined,' 'dove-coloured,' the 'purple-veined,' the 'Ravaccione' (or Sicilian) varieties. Some of these are obtained from the neighbourhood of

with entablature, which belonged to the Temple of Castor and Pollux, and which are formed of Parian marble.—Bœdiker's *Italy*, vol. ii.—The columns from Trajan's forum are also of Greek marble. The Roman sculptors distinguish the Parian and Pentellic marbles from those of Carrara by the brighter glistering of the crystal facets shown by a fresh surface of the former as compared with those of the latter.

Serravezza, Massa, and the Monti Pisani. Of this last-named, a white marble from the Bagno della Duchessa, near Asciano, the campanile (or 'leaning tower,' as it is called), and much of the Duomo and Baptistry of Pisa are constructed.

Bardiglio. This is a marble in much request. It is of a grey or bluish colour, traversed by dark veins; and a variety in which the veining assumes the appearance of flowers, is known as *bardiglio fiorito.* It is obtained at Montalto, on the southern borders of Tuscany, and the coast near Genoa.[1] Another marble, somewhat less esteemed than the above, is the *bardiglio scuro* of Italian sculptors. It consists of saccharoid limestone, containing carbonaceous matter, which imparts to it a grey or bluish colour.

Yellow Marbles are found at Mount Pelli in Tuscany, at Torri on Lake Garda, Volterra and Poggio di Rossa, near Sienna, in Tuscany; at Gorno and Albino in Venetia.

Grey Tiburtine Marble is obtained from the neighbourhood of Cesi, near Terni, immediately beneath the red 'cottanello' marble, as described by Sir R. Murchison, in the Memoir already referred to.

[1] These marbles lie at the base of the Liasso-jurassic rocks of Tuscany, and are quarried in the deep gorges near Stazzemma. They are overlaid by cleaved slates, largely worked for roofing purposes. Sir R. Murchison, Journ. Geol. Soc. v. 267.

Black Marbles, or those with a black base variegated, are found at Castel Nuovo nel canavesata, in Piedmont; at Como, in the Milanais; at Barga, Vellerana, and Porto Venere, in Tuscany; at Guzzaniga, in Brescia; and Santa Maria del Bosco, in Bergama.

Red Marbles (or *Rose-coloured*) are found at Ambrogio di val Policella in Veronais, at Trepani in Sicily, near Sienna in Tuscany, and near Florence. There are also numerous brecciated marbles in Tuscany. The red marble of the Roman States ('cottanello') is obtained from Cesi, near Terni, and is considered by Sir R. Murchison to belong to the Oxfordian stage, as it contains *Ammonites biplix*, &c.[1] Of this marble the great columns which support the arches of the side aisles of St. Peter's are formed.

Greenish Marbles are found at Serravezza, in Piedmont; at Improneta, near Florence; and at Trepani, in Sicily. Besides these, there are brecciated green marbles and serpentines, described elsewhere (Page 106).

Verona. The white, cream-coloured, and reddish marble of Verona, is derived from the nummulite limestone formation which crops out in the banks of the Adige, and rises into picturesque vine-clad eminences to the north of that impetuous river. This marble is seldom crystalline, yet it takes a very good polish, and has been employed from ancient

[1] Journ. Geol. Soc. v. 271.

times; as the Roman Amphitheatre, supposed to have been built by Diocletian in the third century, is constructed of this stone; occasionally the forms of the fossil shell (Nummulites), which gives the name to the formation, may be sometimes faintly distinguished amongst the blocks of the Amphitheatre.

This marble, in some cases, assumes a brecciated aspect, examples of which may be observed in the porch and internal columns of the Cathedral of Verona;[1] the external walls of which are constructed of alternating courses of marble and brick, with ornamental designs in terra cotta, of the twelfth century.

The marble of Verona has been extensively employed in the construction of the nobler buildings of Venice. Of this stone are formed the columns and arches of the two colonnades which run along the south and west sides of the Palace of the Doges, dating from the fourteenth century. We also recognise it in the portal of St. Mark's, in company with other marbles; the campanile, and the internal flooring of the Accademia delle Belle Arti, and some of the churches. It is scarcely necessary to add that all the stone used in Venice has been brought from long distances.

Additional Localities. Other sources of statuary

[1] This quaint old structure has a certain celebrity besides its intrinsic merits attached to it, as it contains Titian's celebrated picture of 'The Assumption.'

marble in Italy are Schlanders, in the Tyrol, and Monte Candido, lying to the north of the Lago Maggiore, from which the material for the construction of Milan Cathedral, one of the most elaborately ornamental structures in the world, has been brought. Of the beauty of this church it is impossible to speak too highly: the whole building, with the exception of the basement story, is constructed of white marble, elaborately carved, or adorned with statuary, up to the roof, and surmounting the highest pinnacles; and of these latter there are several gems of art by the hand of Canova.[1]

The following list of quarries in the Apuan Alps, near Carrara, Serravezza, and Massa, has been compiled by Mr. W. P. Jervis, F.G.S.[2]

	Name of Quarry.	Quality of Marble.
1	Crestola	Statuary.
2	Mossa	Veined Statuary.
3	Cavetta	Statuary.
4	Zampone	Statuary, bardiglio.
5	Poggio Silvestro	Statuary.
6	Betogli	Statuary.
7	Polvaccio	Statuary.
8	Carpevola	Statuary, paonazzo.
9	Fossa degli Angioli	Ordinary and white marble.
10	Piastra	
11	Grotto Colombara	
12	Ravaccione	

[1] Amongst the statues of the other saints which are perched on the pinnacles of Milan Cathedral is that of the Emperor Napoleon I.

[2] Mineral Resources of Italy, Lond. 1862.

Name of Quarry.	Quality of Marble.
13 Canal Bianco	Best ordinary.
14 Vallini	Ordinary.
15 Porcinachia	Veined white, bardiglio.
16 Boccanaglia	Veined white, bardiglio, & paonazzo.
17 Pescina	Veined white, bardiglio breccia.
18 Calacatta	Statuary, veined white, bardiglio.
19 Canal Piciniro	Veined white, bardiglio.
20 Valbona	Veined white.
21 Fantiscritti	Bluish ordinary.
22–3 Para, and Vara	Fine white veined, large blocks.
24 Belgia	Ordinary, veined bardiglio.
25 Fossa cava	Veined white, ordinary.
26 Artana	Bardiglio fiorto.
27 Falcovaja	Statuary, ordinary.
28 Carchio	Statuary.
29 Polla	Statuary.
30 Rondone	Mischio.
31 Fontanaccia	Bardiglio fiorto.
32–5 Fornetto	Statuary and white ordinary.
36 Mine of Buca alla Vena	White marble, with veins of magnetite.
37 Carchio	White marble.
38 Canal D'Agiola	Ordinary, bardiglio.
39 La Costa	White.
40 Ceragiola and Borrone	Common white.
42 Giardino	Best statuary, ordinary.
43 Mont' Alto	Bardiglio fiorto.
44 Messette	Bardiglio fiorto.
45 La Ratta	Slate quarry.
46 Pisciarotti	Bardiglio fiorto.
47 Solajo	Ordinary.
48–9 Battaglino	Common white.
50 Piastrajo	Mischio breccia.
51 La Fontana	Bardiglio fiorto.
52 Capella	Ordinary.
53 Sandstone Quarry, Monte Volegno.	
54 Pietra da Scalina.	

Name of Quarry.	Quality of Marble.
55 Trambiserra	Statuary, ordinary.
56 Vestito	Mischio.
57 Canal Bertone	Ordinary.
58 Poggio di Cipolo	Ordinary.
59 Vellini	Ordinary.
60 Campo Francisco	Statuary.
62 Sponda	Statuary.
63 Fondone	Statuary.
64 Campanice	Statuary.
65 Crocicchia	Statuary.
66 Monte Brugiana	Ordinary.
67 Nido del Corvo	Ordinary, red stalactite.
68 Al Ficale	Mischio.
69 Sordola	Spotted white.
71 Cerignano	White, black bardiglio.

Greece. How far the excellence of ancient Greek sculpture was due to the suitability of the material for high art which that country produced, it is unnecessary to discuss; but no one can doubt that the presence of Parian and Pentellic marble exerted a certain influence upon the minds of the Athenian and Corinthian sculptors; and that when they found at hand the material for embodying their ideas, in its greatest purity and suitability of texture, they were encouraged to aim at perfection in the design and execution. As Mr. Ruskin well observes of statuary marble, it is exactly of the consistence best adapted for sculpture; that is to say, neither hard, nor brittle, nor flaky, nor splintery, but uniform and delicately—yet not ignobly—soft; exactly so soft as to allow the sculptor to work it without force, and

trace on it the finest lines of finished form; and yet so hard as never to betray the touch, or moulder away beneath the steel.[1] In truth, the genius of Phidias, Scopas, and Praxiteles found in the island of Paros, and in the Mount of Pentelicus, a material admirably adapted for the embodiment of its highest conceptions.

Parian and Pentellic marbles are composed of nearly pure carbonate of lime, with a finely crystalline granular structure, doubtless due, as in the case of the crystalline marble of Carrara, to metamorphic action. The Parian stone, however, on being freshly fractured, presents a glistering play of light from the crystalline facets, of greater brightness than that from a similar surface of the Carrara stone. This distinction can be detected by the skilled Roman workman of the present day, and is one means whereby he is enabled to determine the origin of a fragment of Greek or Italian statuary.

The ancient quarries are situated in the island of Paros, and in Mounts Pentelicus and Hymettos. The Parthenon at Athens is constructed of Pentellic marble. These quarries, besides others, in the islands of Scio, Samos, and Lesbos, afforded materials both for the construction and decoration of the temples of ancient Greece and Rome, but are now rarely resorted to. The Pentellic quarries, however, have

[1] Stones of Venice, III. i.

recently been re-opened, for the restoration of some of the buildings in Athens; and, let us hope, for the use of sculptors all over the world.

In illustration of the preference of sculptors for Greek marble, and its superiority to that of Carrara, the following anecdote may be related.[1] The sculptor Pacetti, having purchased a torso of a male figure, a Greek work of the best period, in Pentellic marble, and desiring to restore it, was unable to find marble of sufficient purity or fineness of texture to match the original, and was consequently obliged to destroy another Greek statue of inferior merit, in order to match it. Pacetti succeeded, and produced the sleeping figure known in art under the name of 'Barberini Faun.'[2]

Any attempt to adequately illustrate the works of art to which the Greek marbles have been applied would be far beyond the scope of this work, even if it were within the ability of the author; a very few examples, therefore, will here only be noticed.

[1] See Recollections, by Massimo D'Azeglio, Eng. ver.

[2] Poor Pacetti was not allowed to reap the reward of his successful labours. Having sold the work to a German Prince for several thousand scudi, the Pontifical Government forbade its removal from Rome, and actually sent an armed band to break into the studio of the sculptor and carry away the statue by force! In vain did Pacetti appeal to the corrupt tribunals for restitution; and thus cruelly wronged, took to his bed and died. It was only some years after that his executors were enabled by a process of law to come to some terms with the authorities. The whole case is related by Massimo D'Azeglio.

And first let us turn to the seat of ancient art itself, Athens, with its Acropolis grand and beautiful in its desolation, once adorned by the noble Parthenon,[1] the Erechtheum, and the temple of Athene Nyke, together with the numerous shrines and statues, including the gigantic *Athene Promachus* of Phidias, 66 feet in height, clad in armour, with a lance whose gilded point formed a landmark to mariners as they approached the harbour of Piræus from Cape Sunion; the whole of this wonderful museum of art being approached by the Propylæa, the noblest gateway, perhaps, ever erected. With the exception of some small portions of these works of foreign marbles, the remainder were formed from the white crystalline rocks of Paros and Pentelicus. Ancient Rome was also adorned with architectural monuments in Greek marble, erected before the Christian era, of which the three Corinthian columns with their entablatures which belonged to the temple of Castor and Pollux, and which now stand in solitary grandeur amidst the ruins of the Forum Romanum, are conspicuous examples. Although dating as far back

[1] The Parthenon had stood almost intact down to 1684, when during a siege by the Venetians a shell exploded the powder magazine which it contained, and reduced it almost to ruins. In this state it was found by Lord Elgin, who in 1801 carried away to England a number of the metopes, a portion of the frieze, and the best statues of the tympana, the works of Phidias and Praxiteles.

as nearly 500 years before our era (B.C. 496), they are still in remarkably good preservation.

Amongst the countless illustrations of the use of Greek marble in statuary, it is difficult to select even a few examples, especially after a visit to the galleries of Florence, Rome, and Naples; where, from the number of specimens recovered from the ruins of ancient cities, we may conjecture how numerous must have been those that are lost. As an example of the beautiful, the Venus de Medici, found in the villa of Hadrian near Tivoli, now deposited in the Galleria degli Uffizi, at Florence, would by many be considered as entitled to the first place; an opinion in which I do not concur. Then the group of Niobe and her children, fourteen in number, which must originally have adorned the portico of a temple. This truly marvellous group of figures, when we consider the variety of attitudes they exhibit, supposed to be copies of works by Scopas or Praxiteles, was found in Rome in 1583, is now in the Uffizi Gallery at Florence. The group of Laocoon and his two sons, the original of which is in the Vatican Gallery at Rome; the torso of Hercules, in the same collection; and the draped figure of Sophocles larger than life, found at Terracina in 1838, and now preserved in the Gallery of the Lateran at Rome, are all of Grecian marble.

Admirable as are these works of art, they are not superior, as it seems to me, in boldness and largeness

of design to the group known as the 'Farnese Bull' found in a mutilated state in the Thermæ of Caracalla at Rome, and now in the Museum of Naples. This group, consisting of seven distinct figures, if we include the bull and a dog, all larger than life, and in various positions and attitudes, is probably unsurpassed for boldness of design and vigour of execution by any group of statuary in the world. The whole group was originally cut out of a single block, which must have been of huge dimensions, by the Rhodian sculptors Apollonius and Tauriscus. When found, it was in a fragmentary state, but it has been admirably restored under the superintendence of Michael Angelo.[1]

Sicily. The marbles of Sicily are but little used in this country. The following are some of the varieties:—Marmo di Trapani, of a grey colour; Marmo di Castelnuovo and di Segesta, of a yellow colour; Marmo di Taormina and Ogliastro, of a red colour; and that of Castelaccio, of a grey colour.[2]

Corsica produces a greyish variegated variety known as the *bardiglio* marble, similar in appearance to that of Northern Italy, and bearing the same name.

France and Belgium. These countries yield several varieties of marble of great beauty; of the

[1] The new portions are the head of the bull, the Antiope with the exception of the feet, the upper part of the Dirce, and a great part of Amphion and Zethus. [2] Gwilt, Encyc. Arch. p. 491.

colours red, rose, brecciated (*brêche*), white statuary, and white-veined black of Saint Mont Clarie, and black and gold. The following are some of the localities as given by Chateau. Gap in the Hautes Alpes; greyish black, easy to work. Besançon in the Doubs; tufaceous marble of different qualities. Combovin in Drôme; fine white marble employed in architecture and sculpture. Chartes in Ure-et-Loir; beautiful conglomerate, susceptible of polish. Montpellier in Herault; very hard, durable, and handsome stone. Lourdes in Hautes Pyrénées; white and grey with black veins, of good quality. Château-Landon near Némours; grey, variegated with yellow, susceptible of good polish, and largely employed for decorative purposes in Paris:[1] this marble is derived from Tertiary strata.

Spain. This country, from its geological structure, may be safely inferred to be rich in marbles, which in the period of her magnificence were employed in the interior decoration of her numerous splendid buildings. It is probable, however, that the marbles of Italy were largely employed in ecclesiastical edifices, since the architects of Spain during the middle ages seem to have had close intercourse with those of Italy. White marble from Machael in the Sierra di Bacares,

[1] For example, in the pavement of the Pantheon; the basement of the now prostrate Arc de Triomphe; parapets of the bridge of the Tuileries; the fountain of St. Sulpice; the bridge of Némours; and the basins of the Château d'Eau. Chateau, Tech. d. Bât. i. 231, 2.

was employed in the Alhambra, and more recently in buildings of Madrid, and Baza. Similar marbles are obtained from Velez-Rubio in Andalusia, from Valencia, and from Rosas in the Eastern Pyrenees; red marble veined from Murcia and Cueta in Leon; shelly marble of a deep black ground from Badajos; and statuary marble from Filabra in Grenada.

Portugal, also, produces several good varieties of marble; that known as the 'Emperor's Red,' of which a fine block was presented by the late Don Pedro, King of Portugal, to Queen Victoria for the royal mausoleum at Frogmore, being the most highly prized. White marbles are found at Estrennas and Vianna; yellow and red at Alentejo and Troncao; blue at Serpa and Villaviciosa; and a peculiar variety called 'agate marble' at Alentejo.

Gibraltar. Amongst the caverns with which The Rock abounds, stalagmites and stalactites are found which have been formed by deposition from dripping water. These, when cut and polished, often afford a very handsome banded and concretionary marble, which has obtained some celebrity under the name of 'Gibraltar stone;' and is cut and moulded into small articles such as inkstands, cups, and candlesticks.

Phrygian Marble. One of the most curious, as well as handsome varieties of marble with which I am acquainted, is largely used in Southern Italy in the internal construction of churches and buildings of

a higher class. It is known as 'Phrygian' marble, or 'Pavonazetta,' from its resemblance to plumage of a peacock. It consists of banded layers of silicious limestone of various shades of green, verging upon blue or grey, alternating with others of a pure white. These bands are sometimes contorted, waved, or foliated in a remarkable manner, characteristic of schistose rocks; and in some instances the different layers are broken through and displaced by little 'faults' or slips, as may be observed in one of the four beautiful columns which adorn one of the courts in the Vatican Gallery. The finest examples of the use of this marble are to be seen in the Church of S. Maria sopra Minerva in Rome, in which the columns between the nave and side aisles are formed of it, and are beautifully polished. In these the wavy foliation and banded structure are brought out in perfection.

The use of this species of marble reaches far back into Roman history. I observed a pillar of it amongst the ruins of Pompeii,[1] and the Corinthian columns in a dilapidated state, standing on the north side of the Forum Romanum, which once formed the porch of the Temple of Faustina, but are now converted into a porch for the Church of S. Lorenzo di Miranda, sufficiently attest its use at the commencement of the Christian era.

[1] Another of these columns of Phrygian marble from Pompeii is placed in the Museum at Naples.

CHAPTER III.

MARBLES OF THE AMERICAN CONTINENT.

Canada. The crystalline limestones of the Laurentian series of rocks yield white marbles suited for decorative purposes, but not for statuary; they are quarried at Calumet Falls on the Ottawa, Portage du Fort, and Fitzroy Harbour. Large blocks of pure white are obtained from Elzivir and Marmora; and the statuary marble from Barrie would probably not be inferior to that of Carrara, were it not for grains and specks of quartz and tremolite, which detract from its excellence in quality.[1]

Coloured marbles are obtained from the rocks at the mouth of the Madawaska, in Mac Nab county, on the Ottawa; the colours are grey, and dark grey variegated; it can be raised in large blocks. A rich red variety is also found amongst the Quebec series of strata at St. Joseph on the Chaudière.[2]

Nova Scotia, &c. Marble occurs sparingly in the eastern states of British America; but coloured varieties are found amongst the Carboniferous limestone strata at Fraser's Mountain and Little Harbour

[1] Logan, Geol. of Canada, p. 823. [2] *Ibid.*

near New Glasgow ; at Plaistow Cove, in Co. Inverness; and in Long Island, Cape Breton. White marble occurs amongst the metamorphic schists of Five Islands in Nova Scotia, together with coloured serpentinous marble.[1]

United States. Statuary marble has been obtained in the U. S., but not of a quality equal to that of Europe. Good ornamental marbles are quarried at Sheffield, Great Barrington, and Lanesborough, in Berkshire, Mass.[2] The columns of the Girard College are from Sheffield, where blocks 50 feet long are sometimes quarried. The marble front of the City Hall, the Custom House, and University of New York, are built of stone from West Stockbridge; that of the Capitol at Albany, from Lanesborough. At Stoneham there is fine statuary marble, but large blocks are not easily obtained. The variety from Great Barrington is handsome and clouded. There are marble quarries also in Vermont, in several counties in the State of New York, at Smithfield in Rhode Island (statuary), near Hagerstown in Maryland, and and a fine clouded variety near Philadelphia. A dun-coloured marble is obtained at New Ashford and Sheffield, Mass., and at Pittsford, Vt.[3]

Black marble used in the U. S. comes mostly from

[1] Dawson, Acad. Geol. p. 593.
[2] Hitchcock, Geol. Rep. p. 162.
[3] Dana, Man. Miner. p. 363.

Shoreham, Vt., and other places in that state near Lake Champlain; there are also quarries at Isle La Motte, near Plattsburgh, and Glenn's Falls, New York. Grey and dove-coloured marbles are common throughout the Western States. There are also varieties of shell marble, encrinital marble, and madrepore marble from numerous localities.[1]

[1] Dana, Man. Miner. pp. 365–6.

CHAPTER IV.

MARBLES OF OTHER COUNTRIES.

Egypt. Breccia di Verde. Between the Red Sea and the Nile, in lat. 26° 8′ N. (nearly), the celebrated Breccia di Verde, which has been largely used for ornamental purposes in Italy, is found. It reposes on slates in conformable thick-bedded strata, becoming more horizontal as it recedes from the central granitic axis. It is a beautiful rock, composed of angular, or rounded, pebbles of greenstone, gneiss, porphyry, slate, serpentine and marble, cemented together by a compact calcareous paste, varying from all shades of green to a purplish red. Between Siddt and Hummamet this breccia has been quarried by the ancient Egyptians, whose chisel-marks and hieroglyphics are as sharp and legible as though only cut yesterday. The churches of Italy and the mosques of Constantinople contain numerous examples of this marble; while one of the most perfect and beautifully sculptured specimens of art that remain in Egypt is the celebrated sarcophagus, supposed by Dr. Clarke to have contained the body of Alexander the Great.[1]

[1] Lieut. Newbold, from Geol. Soc. Lond. iv. 329.

Onyx Marble. The re-discovery of the quarries from which the now justly-admired 'onyx marble' was formerly extracted, by a French gentleman, M. Delmonte, in 1849, is an event of interest to petrographers. This stone, which is carbonate of lime, was formerly considered to exist only in a state of stalagmite in some limestone caves, but M. Delmonte discovered large beds of it amongst the Tertiary limestones of Blad Recam ('Marble Country') near the ravine of Oned-Abdallah. The old quarries which supplied the inhabitants of Rome and Carthage with this fine translucent marble, which was used in the internal decoration of their houses and monuments, were here situated. This marble, re-discovered after the lapse of more than a thousand years, is now imported into Paris, where it has assumed its former celebrity.[1]

The onyx marble is translucent, faintly white, and iridiscent, of uniform texture and stalagmite structure bearing a resemblance to onyx, whence its name. It produces a beautiful material for the manufacture of timepieces, small vases, candlesticks and similar articles of every-day use;[2] and was in ancient times cut into small vases for holding precious ointments. Onyx marble was one of the stones designated 'Oriental ala-

[1] From MS. account by M. A. Gages, M.R.I.A., Curator of the Museum of the Royal College of Science, Dublin.

[2] A cup ornamented with garnets is in the gallery of this museum; some of the timepieces manufactured in this material in Paris are extremely handsome.

baster,' but is of course altogether a different substance from the alabaster of the present day. 'Oriental alabaster' is another variety of marble also derived from quarries in Egypt, and employed in works of art, except statuary, both in ancient and mediæval times. Its stalactitic origin is at once apparent upon inspection. The colour is that of amber, or rich yellowish-brown, of various shades arranged in folds, or wavy parallel bands. Sometimes it is beautifully iridiscent, as in the case of the four columns, each about eight feet in height, which adorn the sala containing the cabinets of gems in the Galleria degli Uffizi at Florence. The mammillated structure, so characteristic of deposits due to filtration or percolation, is also not infrequent. This stone was largely employed by the ancient inhabitants of Egypt in the formation of canopi (or jars surmounted by sculptured images of the dog-headed god), in which were deposited the ashes of the dead, and of which examples may be seen in the British Museum, the Louvre, and the Galleries of Rome and Naples.[1] Besides these smaller objects, large cinneral urns were formed of this material; one of the finest I have seen being in the Museum of the Vatican at Rome, which measures about 9 feet in length, and 4 in depth. There is another in the Egyptian collection at Naples; and the Galleria Pitti

[1] One of these canopi is deposited in the Museum of the Royal College of Science, Dublin.

at Florence contains tables of this material showing the banded and concretionary structure very beautifully developed.

Palestine. Marbles were used without stint in the decoration of Solomon's Temple, and Palace,[1] and the buildings themselves were constructed of white marble[2] which glistened from afar in the blaze of an unclouded eastern sun. The situation of the quarries from whence the marble was hewn is uncertain; but every block was shaped and polished before it left the quarry, and noiselessly let into its place. Heber has well expressed the silent growth of this the first permanent building erected for the worship of Jehovah, and as the central church of a whole nation:—

> 'No hammer fell; no ponderous axes rung;
> Like some tall pine, the noble fabric sprung:
> Majestic silence!'

Persepolis. The ancient capital of Persia, of which the ruins are situated in the great plain of Istakhr, destroyed by Alexander the Great, 2000 years since, contain amongst its tombs pavements of slabs of marble of great beauty, hewn from the neighbouring mountains. The palace of the Shah of Ispahan, the

[1] 1 Chron. xxix. 3.

[2] Josephus says, 'The body of the temple was built of white stone or marble;' and contrasts this with the 'native stone,' probably nummulite limestone, of the encompassing cloisters. Book viii. sec. 3.

modern capital, is also adorned with twisted columns of Tabriz marble, while white and coloured marbles are profusely used in the interior of the building.

British India. The marbles of India have been very largely employed by the inhabitants from remote periods, and used not only for statuary purposes, but in the construction of temples and palaces. The following are some of the localities from which marble of several varieties has been extracted. Statuary and white marbles of several kinds from the environs of Delhi, Gya, Syepore (of a very pure translucent kind), Tinnevelly, and the district of Nerbudda.[1]

In addition to the above we may mention the following:

At Coimbatore in Madras, there is a marble varying in colour from pink to grey and white, which receives a fine polish, and is worked to a considerable extent.[2]

The grey-veined marble of Assam.

The black marble of Durha, Bengal.

The marble of Bellary, of a canary, or cream colour, presenting varieties of depth of shade. It is extremely compact, and takes a fine polish.[3]

[1] The 'marble rocks' in Nerbudda, formed of white saccharine marble, are celebrated for their beauty. Mr. J. G. Medlicott, Mem. Geol. Survey of India, vol. ii.

[2] Mr. H. F. Blanford, Mem. Geol. Survey, India, vol. i. p. 247.

[3] Chateau, Tech. d. Bât. ii. 573.

CHAPTER V.

ART ILLUSTRATIONS IN MARBLE.

PERHAPS the most ancient sculptures in marble which have been rescued from oblivion are those which decorated the majestic temple of Neptune at Pæstum, which also exhibits, in its short crowded columns and gigantic entablature, that most characteristic specimen of the massy form of the older Doric style of architecture which prevailed amongst the Greek colonies of Sicily and Italy.[1] To the same period (B.C. 400–500) may be referred the sculptures on the metopes of the friezes of the three Sicilian temples in the citadel of Selinus, discovered amongst the ruins in 1823,[2] and now in the Museum at Palermo. Of the character of these early works of art, a recent writer says: 'In the metopes of Selinus, while the lines are firm, and the general contour of the human figure is traced with a tolerable approach to truth, the proportions are ludicrously clumsy, the attitudes stiff and unvaried, and the expression of

[1] Wilkins' Antiquities of Magna Græca, 1807.

[2] By Mr. Harris and Mr. Angell. Casts are to be seen in the British Museum.

all the countenances is a slight and almost silly simper."[1]

In advance both in truthfulness of detail, in vigour of design, and probably in the period of execution, are the sculptured figures on the tablets of the temple of Minerva at Ægina, which were discovered in 1811, and after having been restored by Thorwaldsen, were deposited in the Royal Museum of Munich. The fidelity to nature, and simplicity and strength in design which these sculptures exhibit, have astonished artists, and seem to announce the approach to the succeeding period, when Grecian sculpture reached its zenith of excellence under the master minds of Phidias, Polycletus, Myron, Pythagoras, and Calamis.

Of the numerous and beauteous works of art which arose under the hand of these great masters, we are unhappily only acquainted with architectural sculptures; but several antiques are recognised as being either copies, or more likely, free imitations of their designs, or of those executed by their pupils. The Amazon of the Vatican, a figure in the act of springing forward, with its repetitions, are regarded as copies or imitations of those of either Phidias or Polycletus.[2]

[1] Professor Spalding, Italy and the Italian Islands, vol. i. 153, 5th edit.

[2] Of Phidias: by Müller, Handbuch der Archäologie der Kunst, 417–2, 1835, 2nd edit. Of Polycletus: Gerhard, in the Beschreibung, vol. ii. 168.

On the brow of the Quirinal in Rome stand two colossal and striking figures in marble, each reining in a horse. These statues bear on their pedestals, in Latin characters, the names of Phidias and Praxiteles; artists are almost unenimous in considering them to be, not the actual handiwork of these masters themselves, but copies of Greek works of the age in which those masters lived. But it is to the 'Elgin Marbles,' which once adorned the Parthenon, now in the British Museum, that we owe an acquaintance with the very handiwork of Phidias himself, and of some of his contemporaries: these consist (1) of the reliefs of the metopes, which ran along the frieze of the peristyle, or external colonnade; (2) the uninterrupted series of reliefs which adorned the frieze of the cella; (3) and the statues of heroic size, completely disengaged from the walls, which filled the triangular spaces (tympanæ) of the pediments at both ends of the temple.

The Phigaleian Marbles discovered in 1812, and also transferred to the British Museum, are evidently modelled after the sculptures of the Parthenon; and though inferior in design and execution, as is generally the case with imitations, they are works of high merit.

The ascendancy of the Macedonian monarchy, and the luxury and magnificence to which it gave rise, called forth the powers of the successors of the Phidian

age, and marble came into more general use for private as well as public works of art and sculpture. The names of Scopas, Praxiteles, and Lysippus adorn this age; but few, if any, of the original works of these great masters have been preserved to us. The leading figures in the group of Niobe, which in 1583 was found at Rome, and is now in the Gallery of the Uffizi at Florence, are supposed to be imitations of the group of Scopas commemorated by Pliny. Ancient writers mention numerous works of Praxiteles, chiefly like those of Scopas, in marble; and they are described with sufficient minuteness to enable critics to identify some of those recovered from the ruins of Imperial Rome as free imitations, or copies. Of these may be mentioned the Satyr with the Flute in the Capitoline Museum; Apollo slaying the Lizard, in the Villa Borghese at Rome; and the youthful Cupid, also preserved in Rome, and supposed to be an imitation of the Eros of Parion, or that of Thespiæ.[1]

The Venus de' Medici, which once graced the villa of Hadrian at Tivoli, and now adorns one of the Florentine galleries, is the work of Cleomenes of Athens, who is supposed to have lived about a century and a half after Praxiteles. This is justly considered a work of exquisite grace and beauty; to the same period may be referred the statue called the Fighting Gladiator, found early in the seventeenth century

[1] Spalding, Italy and the Italian Islands, vol. i. 166, 5th edit.

amongst the ruins of the imperial palace at Antium,[1] and the Germanicus of Cleomenes.[2]

With the conquest of Greece, Rome became enriched with her spoils, and the conquerors transferred statues and works of art by hundreds or thousands into Italy. The result was the creation of love of art on the part of the Romans; and the Græco-Roman school arose, of whose works the most celebrated examples which have come down to us are the Apollo Belvedere, discovered about the end of the fifteenth century amongst the ruins of Nero's favourite villa at Antium;[3] a colossal statue, unsurpassed in majesty and grace of proportion, executed in the reign of Nero about the year A.D. 54; the group of Laocoon and his sons, impersonating the scene so vividly described by Virgil, executed by the three Rhodian sculptors, Agesander, his son Athenodorus, and Polydorus, for the Emperor Titus, about the year A.D. 69;[4] and the colossal statue of Hercules, known as the Farnese Hercules, a copy of the original of Lysippus by the Athenian Glycon.[5] To a somewhat later period—but prior to the accession of Constantine—

[1] Now in the Louvre, at Paris.

[2] Also in the Louvre.

[3] In the Museum Pio Clementino, Rome.

[4] Preserved in the Museum of the Vatican.

[5] In the Museum at Naples. A fine copy of this statue of colossal proportions, sculptured in Portland stone by Mr. C. H. Smith, stands in the Hall of the Museum of Practical Geology, London.

belong the mutilated group of the Farnese Bull[1] and the Dying Gladiator.[2] From the accession of Constantine down to the middle ages, the art of sculpture gradually decayed with the decline and fall of the empire; and the rise of the modern school, which attained such excellence under the hand of Thorwaldsen, Santorelli, Canova, Benzoni, Flaxman, Gibson, Engel, and Foley, may be dated from the revival of letters in the sixteenth century, and the excavations commenced by Pope Paul III, which brought to light the Farnese Torso, Hercules, Flora, and Venus Callipygos. From that time the search for antiquities has been uninterrupted, and many galleries formed, at the head of which stand those of Rome, Florence, and Naples.[3]

[1] In the Royal Museum at Naples. See p. 141, *ante*.

[2] In the Museum of the Capitol.

[3] Spalding, Italy and the Italian Islands, vol. i. 215.

PART VII.

CHAPTER I.

ALABASTER.

Gypsum, Gyps (*Germ.*) Chaux sulfatée (*Fr.*)
Spec. grav. 2.28–2.4. Hardness, 1.5–2.

GYPSUM is a hydrous sulphate of lime, consisting in a pure state, of lime, 32.56, sulphuric acid, 46.51, water, 20.93. The name is derived from the Greek γύψος, by which it was known to the ancients, who obtained their supplies chiefly from Cyprus, Phœnicia, and Syria, and applied the material to similar purposes as the moderns.[1] In its crystalline form it occurs as selenite, which is translucent and colourless, limpid or white; or as satin spar, or fibrous gypsum, also colourless, and from its peculiar structure, in-

[1] Bristow, Glos. Min. p. 167. Theophrastus, a Greek writer, who lived about 238 years B.C., in his work, History of Stones ('Περὶ Λιθῶν'), of which there is an English version by Mr. John Hill (edit. 1774), gives a good account of the occurrence and use of gypsum and alabaster, cxii. to cxvi.

dicated by the name, very beautiful when cut into necklaces or small ornaments; in its massive form the stone is known as alabaster.

Alabaster occurs in many formations from the Silurian down to the Tertiary; but is especially abundant in the upper Triassic beds, known as the Keuper of Germany. According to Von Cotta, gypsum may have originated either by the wet or dry process, or by metamorphism from anhydrite; but its most abundant source has been simple precipitation from water probably confined in lakes, and thus becoming supersaturated. On the other hand, beds of limestone may have been converted into gypsum by the percolation through the strata of water charged with sulphuric acid.[1]

Anhydrite. Anhydrit (*Germ.*); Chaux anhydrosulfatée (*Fr.*), is a variety of gypsum free from water; of the normal composition of lime, 41.18, sulphuric acid, 58.82, spec. grav. 2.8–3.0, hardness, 3–3.5, by which it may be distinguished from gypsum, which is much softer. Colour white, or tinged with grey, reddish, or dark-blue. It is generally found associated with massive gypsum, and in Bêx, in Switzerland, the anhydrite is found at a depth of about seventy or a hundred feet underneath gypsum, which has been formed from it by absorption of water. Anhydrite, like gypsum, is found associated with rock salt, and

[1] Bischof, Chem. and Phys. Geol. i. 419 (Eng. trans.)

imbedded in clay, marl, and limestone. Its chief sources are Val Canaria, and Bêx in Switzerland; Osterode, Ilfeld, and Walkeuried in the Harz; Mansfeld, Magdeburg, Sulz on the Neckar (of a fine blue colour), Lüneburg in Hanover, Segeberg in Holstein, Hall in the Tyrol, Hallein and Auszee near Salzburg, Berchtesgaden in Bavaria, Vic in Lothringen, Bochnia and Wieliczka in Galicia.[1] Anhydrite, when combined with a small proportion of silex (Vulpinite), is sometimes cut and polished for ornamental purposes.

British Localities. The chief source of British gypsum is the New Red Marl of the Triassic formation, from which it is derived in considerable quantities, both in the central and north-eastern counties of England. In such positions it is frequently associated with rock-salt. Thus, at Droitwich, in Worcestershire, a bed of gypsum, from 40 to 100 feet in thickness, is penetrated, from beneath which brine ascends with force. This brine occupies a space of about 22 inch. in vertical depth, and rests on a floor of rock-salt, with a roof of gypsum, as already stated. The intervening space was doubtless once occupied by rock-salt itself, which has since been carried away, dissolved in water by natural and artificial processes.[2]

[1] Zirkel, Petrog. i. 268.

[2] E. Hull, 'On the Triassic and Permian Rocks of the Midland Counties,' Mem. Geol. Survey, (1869); L. Horner, Trans. Geol. Soc. ii. 94.

The locality which probably yields the largest quantity of English gypsum, is Chellaston Hill, near Derby. Here the mineral occurs in a continuous bed, sometimes 12 feet in thickness, outcropping round the flanks of the hill. It is associated with beautiful bands of the fibrous variety, the 'fibres' (or prismatic crystals) being arranged in a position at right angles to the planes of bedding. The gypsum of this locality is seldom sufficiently pure to be employed for ornamental purposes, and is chiefly used in the manufacture of 'plaster of Paris.'[1] Other localities are Orston, near Grantham; the neighbourhood of Newark-on-Trent; Fauld, near Tutbury; St. Bees' Head, Whitehaven; several localities in Nottinghamshire and Staffordshire; Alston, in Cumberland; and in the vicinity of Watchet, in Somersetshire, where it is occasionally collected on the coast, and sent to Bristol, Swansea, and some other places on the Bristol Channel.[2] Also, in the Isle of

[1] This is done by calcining the stone in order to expel the water (temperature 200° C.), when it falls into a white powder. When water is again poured on the calcined stone, it combines to form a hydrate, and reassumes its original hardness and density. The aggregate annual consumption of gypsum in this country is estimated by Mr. R. Hunt at 30,000 tons, valued at £10,000, the largest quantities being used in the Staffordshire Potteries, where it is employed to form moulds of plaster; hence it is there called 'Potter's stone.'—Descrip. Guide Mus. Prac. Geology, pp. 26, 34.

[2] Bristow, Glos. Min., art. Gyps.

Purbeck, in Dorsetshire, forming large concretions in the lower Purbeck strata.[1]

Ireland. Gypsum occurs in several localities in Ireland. At Carrickfergus, in Co. Antrim, it is found associated with rock-salt, in the Keuper marl of the Triassic formation. In the neighbourhood of Carrickmacross, Co. Monaghan, it forms a thick deposit in the same formation;[2] and it has also been found on the banks of Lough Allen, County Leitrim.

Alabaster has been largely used in the formation of ornamental tombs and statuary preserved in the Cathedrals and Parish Churches of England; probably much of the stone used for this purpose was brought from the Continent.

France. The chief source of gypsum in France was formerly the fresh-water strata of the Tertiary formation of the Paris basin, chiefly at Montmartre and Pantin, associated with sulphate of strontia. It is from these quarries that the 'plaster of Paris' is derived, and which is more valued than that from England, owing to its superior hardness.[3] These

[1] Bristow, Glos. Min., art. Gyps. A large pedestal and tazza of alabaster from Fauld, Staffordshire, worked by Messrs. Hall, of Derby, is placed in the Hall of the Museum of Practical Geology, London.

[2] A polished slab from this locality is deposited in the Museum of the College of Science, Dublin.

[3] Gwilt, Encyc. Arch. p. 542. From these quarries the illustrious

quarries also yield a peculiarly pure variety of alabaster, known by a sacred name I forbear to mention, and which is used in modelling in plaster. Gypsum is also found in New Red Marl (*marnes irisées*) of the east of France, and in the lacustrine deposits of Auvergne and Aix; in the latter containing an admixture of 8 per cent of carbonate of lime.[1] A fine saccharoid variety occurs near Salins and Lons-le-Saurier, in the department of the Jura.

Spain. Some of the Spanish localities are Cervetto, Castelnau de Durban, in the Pyrenees; San Jago de Compostella, in Gallicia; Paredes, in Guadalaxara; Conilla, near Cadiz; and Ternel, in Aragon, with mica as an accessory.[2]

Germany, Switzerland, and Austria. Rittelsthal, near Eisenach; Tonna, in Saxe-Coburg; Golling, near Salzburg, in company with rock-salt; as also at Segeberg, in Holstein; Hasmersheim, in Baden; and Lauenburg, in Hanover. It also occurs amongst the crystalline schists of the Alps and Tyrol; and, along with anhydrite, at Bêx, and Val Canaria, in Switzerland.

Cuvier obtained the bones of extinct animals, from which he made the restorations described in his *Ossements Fossiles*, which laid the foundation of his fame as the greatest comparative anatomist of modern times.

[1] Bristow, Glos. Min. Chateau, Technologie du Bâtiment, vol. i. pp. 88, 92.

[2] Zirkel, Petrog. i. 260, 1.

Italy. Gypsum and alabaster occur in several parts of Italy, and in a state of much purity. In Tuscany it occurs at Miemo, with bitter-spar; also at Fontibagni and Castellina,[1] and at Aosta, in Piedmont. The alabaster of the Val di Marmolago, near Castellina, 25 miles from Volterra, is the purest of all the Italian varieties, and is cut into vases, statuettes, cups, tazze, &c. The alabaster of Volterra, or 'agate gypsum' (Marmo di Volterra), is also a fine variety, veined, and resembling white wax; yellowish and red varieties come from Monte Catini; and a mottled variety, resembling granite (granite gypsum), is obtained from Carrara. Sculpturing in alabaster is carried on with great activity and success in Florence, Volterra, Pisa, and other cities of Central Italy. The art dates from ancient Etruscan times, when Volterra, the centre of this kind of sculpture, was a considerable fortress; and it was the custom to inter distinguished citizens in sarcophagi or cinerary urns of alabaster, formed of a single block, with elaborate mythological sculpturings, and surmounted by a reclining figure of the deceased. The Etruscan Museum at Volterra contains a rich collection of such objects, and which are in excellent preservation.[2]

[1] Hamilton, Quart. Journ. of the Geological Society, London, i. 283 (1845).

[2] Mr. W. P. Jervis, Mineral Resources of Italy, 1862.

The following is a summary of the Italian varieties:—

Statuary	Val di Marmolajo.
White	Pomarance, Allacio and Ariano (with veined and spotted white).
Agate	Gesseri, Annunziata and Ugliano near Volterra; Fontebagni.
Yellow agate and yellow .	Cassaglia, S. Lorenzo.
White and yellow	Al Pozza, near Pomarance.
Bardiglio , , , . . .	Torricella, Ariano, and Menamuta, near Volterra.

CHAPTER II.

British Possessions of America. Gypsum is found largely in the Lower Carboniferous rocks of the counties of Cumberland, Hants, and Colchester, in Nova Scotia; as also in the same formation in the counties of Westmoreland, King's, Albert and Victoria, in New Brunswick.[1] In 1863, 8646 barrels of plaster were exported to the United States.[2] In Canada, the chief—indeed, sole—formation yielding beds of workable gypsum is the Onondaga formation of the Upper Silurian period. Large lenticular beds, interstratified with dolomite, have been traced for a distance of 35 miles along the course of the Grand River, from Cayuga to Paris, and are extensively worked, while further discoveries to the north-west of Paris are anticipated. The rock is chiefly used for agricultural purposes.[3]

United States. New York, near Lockport, affords beautiful selenite and snowy gypsum in limestone. At Camillus and Manlius, N.Y., and in Davidson County, Tennessee, are other localities. In the

[1] Particularly on the river Tobequi; Selwyn, Rep. Prog. Geol. Survey, Canada, 1866–9.

[2] Logan, Geol. of Canada, pp. 459, 762.

[3] Dawson, Acad. Geol. pp. 223, 249.

Mammoth Cave, Kentucky, alabaster occurs in singularly beautiful similtudes of flowers, leaves, shrubs, and vines. Massive gypsum occurs west of Syracuse, in New York, and as far as the western extremity of Genessee County, accompanying the rocks which afford the brine springs; also in Ohio, Illinois, Virginia, Tennessee, and Arkansas.[1] A fine blue crystallized anhydrite occurs, with gypsum and calc-spar, in black limestone, at Lockport.[2]

Specialities. Though gypsum is of less value, and inferior in durability and beauty to some varieties of marble, it is extremely useful as an adjunct in the arts, and in making copies of works which are only within reach of the few. One of the most successful of these attempts at imitation is the copy of the Florentine Cup, by Benvenuto Cellini, which is in the Museum of Practical Geology. There are also means by which the plaster may be hardened, and coloured in imitation of marble, by processes which it would be out of place here to describe; but which, in the instance of the model of the 'Dying Gladiator,' moulded in 'Parian cement,' in the hall of the same building, must be considered a successful imitation, though, like all imitations, far inferior in beauty to the original.[3]

[1] Dana, Man. Min. p. 113. [2] *Ibid.* p. 114.

[3] For an account of these processes for making 'fictile ivory,' 'Keene's cement,' 'Parisian cement,' see Descrip. Guide M. P. G. pp. 34, 5, or Gwilt's Encyc. Arch. pp. 540–42.

PART VIII.

THE RARER ORNAMENTAL STONES.

CHAPTER I.

FLUOR-SPAR.

Fluss-spath (*Germ.*); Fluorine, Spathfluor (*Fr.*). Spec. gravity, 3.1–3.2; hardness, 4.0. A fluoride of calcium having a normal composition of fluorine, 48.72, calcium, 51.28.

FLUOR-SPAR is a very handsome ornamental stone, and occurs either massive, or in well-known cubical or octohedral crystals; of various colours, purple, blue, lilac, green, yellow, or (rarely) red. Perfectly limpid to transparent, with vitreous lustre.

Fluor-spar, though locally plentiful, is but sparingly distributed. Its chief source in England is Derbyshire, where it is found in caverns, and mineral veins in the Carboniferous limestone. When cut and polished, it generally presents a series of banded hues, passing from deep purple to light yellow and limpid; and has been worked into vases, cups, obelisks, and various ornaments, with so much skill

and success, as to have received the name of 'Derbyshire spar' throughout the country.[1]

Fluor-spar occurs in the mines of Cornwall, as at Huel Cupid, East Tamar, West Huel, Copper Hill, and North Gambler, near Redruth; Huel Mary Ann, Menhenniot, in fine blue bevelled cubes; near St. Agnes, in translucent cubes of a rich lilac colour. Cumberland, at Cleator Moor, in large yellow, lilac, and green crystals; also at Alston, in cubes which appear green by transmitted light, and blue by reflected light: this effect, termed by Professor Stokes 'fluorescence,' is due to a peculiar refracting power of the first surface on which the light falls.[2]

In Scotland, fluor-spar is found at Balater House, and Glenmuick, Aberdeenshire. In Ireland, in the Glendalough mines, County Wicklow. It is common in the mining districts of Saxony; near Rottleberode and Strassberg in the Harz;[3] in the Thüringer Thal; in the Alten Liebenstein, Meiningen;[4] Münsterthal in Baden; the Lombardian Alps at Monte Presolana, and in the Val di Scalve, north-west of Lago Palzone

[1] The name by which this mineral is known amongst the miners is 'Blue John.' In Bristow's Glossary of Mineralogy, figures of the various crystalline forms of fluor-spar are given. In 1858 about 1500 tons were raised from mines in England.—Mr. R. Hunt, Mineral Statistics, 1858, part ii.

[2] Bristow, Glos. Min. p. 142.

[3] Zirkel, Petrog. i. 192.

[4] Breithaupt, Paragenesis der Minerallien, p. 200.

in Italy.[1] It also occurs massive in the district of Auvergne, central France; as a recent deposit from springs of water at Plombières; and in crystals amongst the lava of Vesuvius.

America. Cubic crystals of a greenish colour, over a foot each way, have been obtained at Muscolonge lake, St. Lawrence, Co. N.Y. Near Shawneetown on the Ohio, a purple fluor in grouped crystals of large size is obtained from limestone; other localities are Westmoreland, N.H., at the notch in the White Mountains, Blue Hill Bay, Maine, &c.[2] It is also met with sparingly in Canada, rarely massive, but generally in crystals of green and purple colours, and associated with its favourite galena. The chief sources are mineral veins on Lake Superior, and in some of the islands; also on Iron Island, Lake Nipissing, and at Bay St. Paul, and Murray Bay.[3]

Specialities. Fluor-spar may be considered to have been formed by deposition from water either along the walls of fissures and mineral veins, or in a stalagmitic form in caverns and hollows in the rocks. In Derbyshire it sometimes forms the gangue of some lead mines, and its association with galena is a subject of common observation amongst mineralogists. The massive varieties receive a high polish, but are difficult to work on account of being

[1] Bristow, Glos. Min. p. 142. [2] Dana, Man. Min. p. 122.
[3] Dr. Bigsby, quoted by Logan, Geology of Canada, p. 463.

brittle. It is usually turned in a lathe, and worked down, first with a fine steel tool, then with a coarse stone, afterwards with pumice and emery; and the crevices are sometimes filled with galena.[1] Fluor-spar supplies fluoric acid, which is employed in etching on glass; it is also used as a flux for metallic ores, hence the name (*fluere*, to flow), for which purpose it is largely employed at the Mansfeld copper works in Germany.[2]

Origin and mode of Occurrence. Fluor-spar occurs in drusy cavities in amygdaloids; in veins and dykes in granite, gneiss, mica slate, porphyry, diorite, and granular limestone; and as already stated, in the case of Vesuvius, in lava. Yet it cannot be argued from this that it is a product of plutonic or volcanic action, as it is also found associated with substances composed of carbon, hydrogen, and oxygen, that are not only not produced but decomposed under the influence of heat; we must therefore conclude with Bischof, that, like the minerals with which it is associated in metallic veins, it has been formed in 'the wet way,' or by precipitation from water.[3]

[1] Rev. Dr. Haughton first drew my attention to this fact, when examining some specimens of minerals from Central France, 1871.

[2] Vases and other objects of art in fluor-spar are so common that it is unnecessary to mention examples. These, however, may be seen in the Hall of the Museum of Practical Geology, South Kensington; and the British Museum.

[3] Bischof, Chem. Geol. ii. 5.

CHAPTER II.

ROCK-CRYSTAL.

Quarzkrystall, *Germ.* (From χρύσταλλος, ice.) Rhombohedral, usually occurs in six-sided prisms, terminated by six-sided pyramids. Spec. grav. 2.5–2.8; hardness, 7.0.

QUARTZ GROUP. In treating on rock-crystal, we feel that we are on the boundary which separates the precious from the ornamental stones; and it is questionable with which of these divisions it ought to be classified, as it in some measure partakes of the character of both. Owing, however, to its use as an ornamental stone, especially by the Florentine artists of the sixteenth century, it is entitled to a place here, if only for a few lines.

Rock-crystal is the transparent, colourless, and crystalline form of pure quartz. It is abundantly distributed in veins and geodes amongst crystalline and metamorphic rocks, but does not often occur in large crystals suitable for working into ornaments in the British Islands. Its limpid transparency and extreme hardness make it a valuable material for the manufacture of ornaments for the person, and lenses for spectacles; and in no manner can it be displayed to greater advantage than when set as cut

stones in a ground of bog-oak for bracelets or necklaces,—a branch of industry pursued with great success in Ireland, from which the stone takes its name of 'Irish diamond.' Its chief sources in this country being Wicklow, Finglen mountain, and Killarney.

Rock-crystal is an essential in many plutonic rocks, but generally occurs thus in an imperfect state of crystallization, as amongst the quartz-porphyries of Galway, Donegal, and Mourne in Ireland, and of North Wales. In the granite of the Mourne mountains it is well developed (as smoke quartz) in cavities along with topaz and beryl. The beautiful yellowish variety known as 'Cairngorm,' from the mountain of that name in the Highlands of Scotland, is a highly prized ornament for brooches, the handles of dirks and knives (*skian dhu*), which form appendages to the Highland garb.

The chief supplies of rock-crystal are from abroad. It is obtained from geodes in the granites of Switzerland, amongst the marble beds of Carrara in Northern Italy,[1] and the sandstones of the Schwarzwald, Hungary; India and Ceylon; Quito; Brazil; Co. Herkimer, in New York State; Diamond Island, Lake George; Pelham and Chesterfield, Mass., U.S. *Rose quartz*, at Albany and Paris, *smoke quartz* at Goshen, *amethyst* at Bristol, and Kewenaw Point, Lake Superior.[2] The

[1] Bristow, Glos. Min.; Von Cotta, Eng. edit. § 6.

[2] Dana, Man. Min. p. 138.

trappean rocks along the northern shore of Lake Superior, yield amethysts in great abundance; and the rock-crystals at Quebec, give rise to unusual modifications of form. Large crystals are also found in the quartz veins of Bruce mine and Harvey's Hill mine of Lower Canada.[1]

Varieties. Smoke quartz. This is a clouded variety, with a brownish tint becoming deep, when it is termed *morion.*

Rose quartz. A pink variety, the colour being probably due to a slight admixture of oxide of manganese.[2]

(*b*) *Amethyst.* Violet or purple colour from oxide of manganese. The finest specimens are obtained from Ceylon, India, Persia, and Siberia.

(*c*) *Chalcedony* (from Chalcedon, in Asia Minor). A milk-white or wavy, translucent variety, approaching smalt-blue, the latter being most rare and highly esteemed. The stone is an intimate mixture of crystalline and amorphous silica; or, according to Fuchs, of silica and some opal disseminated through it.[3] It generally occurs in mammillated and botryoidal forms, exhibiting in cross section parallel layers of slightly varying tints and degrees of trans-

[1] Logan, Geol. of Canada, p. 500.

[2] Hunt, Descrip. Guide M. P. G. p. 141.

[3] Poggend. Annal. xxxi. 577. Bischof concurs in this view, Chem. and Phys. Geol. (Eng. vers.) ii. 464.

parency. From its hardness and toughness it forms an excellent material for the engraver, and is worked into vases, brooches, and ornaments for the person. Fine specimens are procured from Monte Verdi in Tuscany, the amygdaloidal volcanic rocks of Iceland, and the Faröe Islands. Specimens of sponges in chalcedony from the Chalk formation are found on the sea-coast at Bognor, Selsey, Littlehampton, and Worthing.[1]

(*d*) *Agate.* (From ἀγάω, to admire), or from the R. Achates, whence, according to Theophrastus, agates were first brought.[2] Translucent coloured owing to combinations of common quartz, amethyst, jasper, carnelian, and other varieties of quartz, arranged in alternate stripes, or irregularly mixed together.[3] The moss agate is a well-known variety, with moss-like delineations due to oxide of manganese or iron. The chief sources are India and the Brazils.

(*e*) *Jasper*, derived from the Greek Ἴασπις, is another of the many forms under which quartz is presented to us. It differs from agate chiefly in being opaque. Its colours are extremely varied, and are due to the presence of foreign substances, chiefly oxide of iron; which is, indeed, the great colouring agent which nature employs for stones as well as

[1] Bristow, Glos. Min. p. 75.
[2] *Ibid.* p. 4.
[3] B. von Cotta, Rocks class. p. 6.

rocks and mountains.[1] It may be described as a dense, opaque, siliceous rock, of red, purple, blue, and greenish tints, with their modifications; and according to the arrangement of these we have the following varieties:—1. *Riband jasper;* in which the colours are arranged in parallel bands. 2. *Egyptian jasper;* found imbedded in trap, or as pebbles on the banks of the Nile, in which shades of wood-brown, alternating with red, are arranged in concentric wavy zones, which are usually cut across and polished. 3. *Ruin jasper;* a variety presenting a fanciful resemblance to ruins. There are also, 4. *Yellow jasper;* found at Vourla in the bay of Smyrna; and, 5. pebbles of *Red jasper;* on the plains of Argos.[2]

(f) Blood stone, or *heliotrope,* has a deep green base, slightly translucent, containing spots of red, which have some resemblance to drops of blood. In the Louvre at Paris, there is a bust executed in this stone, in which the spots are so arranged as to represent drops of blood.[3]

Jasper is not uncommon amongst the more ancient geological formations. It is abundant in large pebbles or boulders amongst the conglomerates of Mweelrea mountain in the West of Ireland; along the shores of Co. Wexford; and in smaller ones,

[1] A fact well expressed by Mr. Ruskin in 'The Two Paths,' Lect. 5.

[2] Bristow, Glos. Min. p. 195.

[3] Dana, Man. Min. p. 137.

amongst the conglomerate beds of the New Red Sandstone of England. A fine bed of red jasper is found on the eastern shore of Loch Lomond, north of the pass of Balmaha; in bog iron ore at Briesgau in Germany; in the form of pebbles from the sand of the Nile or Desert of Egypt.[1] Fine specimens of riband and other jaspers are obtained from the river Korgon in the Altai, and Orenburg in Siberia.[2] Heliotrope from the Island of Rum, Scotland; Iceland; and Silesia.[3] At Sherbrooke in Canada there is a large bed passing into jasperry iron-ore; and another at Rivière Quelle. Fine pebbles are found in the jasper conglomerate of the Huronian series on the north shore of Lake Huron.[4] In the U.S. red jasper occurs on the banks of the Hudson at Troy, and at Sangus near Boston, Mass.; yellow jasper along with chalcedony at Chester, Mass.; heliotrope occupies veins in slate at Bloomimgrove, Orange County, N.Y.[5]

(g) Opal being a precious, rather than an ornamental stone, its description here would be foreign to the purpose of this treatise.

[1] B. von Cotta, Rocks class. Eng. ver. p. 6.

[2] Of which there are specimens in the Museum of Practical Geology. In the mountains near the river Korgon in the Altai is a mass of jasper 300 feet thick resting on a mass of porphyry.

[3] Hunt, Descrip. Guide M. P. P. p. 142.

[4] Logan, Geol. of Canada, p. 834.

[5] Dana, Man. Min. p. 138.

Onyx is an ornamental siliceous stone, resembling agate, and consisting of layers of opaque white, alternating with others of a yellowish brown, dark brown, or umber colour; when it consists of sard and white chalcedony in alternate layers, it is called *sardonyx*.[1] The tints of onyx may be heightened by boiling it for several days in honey and water, and then soaking it in sulphuric acid to bring out the black and white layers, or in nitric acid, to bring out the red and white layers.[2] Onyx is found in Perthshire; in the Isle of Syke; in the amygdaloid of Antrim; at Oberstein in Saxony; in the South of Russia; Yemen in Arabia; and Guzerat.

Aventurine (or Aventurine quartz) is a vitreous variety of quartz, usually translucent, variegated with tints of grey, brown, reddish-brown, or rose colour, and spangled throughout with scales of golden-yellow mica, or, according to Gahn, by metallic copper, crystallized in the form of flat segments of a regular octohedron. It is obtained from Siberia, Silesia, Bohemia, Cape de Gata in Spain, Egypt, and India. The name is derived from the artificial gold-spangled glass, the art of which was accidentally (*par aventure*) discovered by a workman having let some brass filings fall into a pot of melted glass, which he thereupon named Aventurine.[3]

[1] Dana, Man. Min. p. 136.
[2] Bristow, Glos. Min. p. 266.
[3] *Ibid.* p. 31.

CHAPTER III.

ART ILLUSTRATIONS.

SCULPTURING. Sculpturing in various ornamental stones of the quartz family has been practised from very early ages. Descending from the times of Jewish history through the period of high art in Greece and Rome, down to the comparatively modern times of the sixteenth and seventeenth centuries, the glyptic art was practised largely and most successfully by Italian artists, as also those of Germany, France, and England.[1] Many of these gems of art have been preserved to the present day; a circumstance, as Mr. J. C. Robinson has remarked,[2] due not only to the intrinsic value and beauty of the objects themselves, but to the imperishable nature of the material out of which they have been formed; for while thousands of sculptured rings and personal ornaments have come down to us from the days of the Roman emperors, it is not improbable that thousands more

[1] The art of sculpturing and fashioning jasper, chalcedony, rock-crystal and other stones was practised during the fourteenth century by French and German artists. Some beautiful specimens of their work is in the collection of the Marquis of Salisbury.

[2] Catalogue of the Special Exhibition of Art-treasures at South Kensington, 1862.

are hidden beneath the soil, retaining the sharpness of original sculpture, and only awaiting some accident to bring them to light.

During the sixteenth century, the Italian artists, especially those of Florence, exhibited great skill and taste in fashioning cups, vases, ewers, and similar articles in rock-crystal, jasper, agate, chalcedony, and lapis-lazuli; while they also re-mounted and decorated with jewels and enamel similar objects which had been preserved from the days of ancient Greece and Rome. Of this, the onyx ewer, taken at the sack of the summer palace of the Emperor of China, which I shall presently more fully describe, may be cited as an illustration. Many of these beauteous examples of industry and skill adorn British and foreign cabinets, especially those of the Queen, of the Dukes of Marlborough and Devonshire, of Lords Carlisle and Salisbury, and were freely lent by the owners to the South Kensington Museum for special exhibition in 1862.[1] The Museum of the Louvre, rich in works of art sculptured in precious stones which have formed part of the treasures of kings and princes of France, is especially rich in examples fashioned in rock-crystal. The Imperial Treasury of Vienna, and the Green Vaults of Dresden are also the repositories of similar examples of handiwork; amongst which fine crystal

[1] Fuller descriptions will be found in the catalogue drawn up by Mr. J. C. Robinson, F.S.A., and Mr. G. W. Chaffer, F.S.A.

cups by a Milanese artist may be specially noticed. I now proceed to briefly notice a few, from amongst the many, splendid examples of glyptic art exhibited at South Kensington in 1862.

1. Fragment of a magnificent antique cameo in onyx of three layers; representing a head and bust of Jupiter with the ægis. When complete this gem must have measured about three and a half inches high by two and a half in width. It is engraved in the 'Dactyliotheca Smithiana.'

2. Large cameo, executed in sardonyx of many strata; a laureated head and bust of an emperor, with the ægis, surrounded by a raised border enriched with ovolo moulding. It is, perhaps, the largest in existence, being seven and a half inches high by five and a half wide, and belonged to King Charles I. It was unfortunately broken by a lady of the court, and was afterwards rather badly set, but none of the fragments are lost.[1]

3. Large cameos with busts of Henry VIII, and Queen Elizabeth.

4. A crystal vessel in the form of a flying fish, the body and fins of one large piece; the head and tail joined by silver mounts, set with stones carved with

[1] According to Van der Doort, who made an inventory of the articles belonging to the King, the culprit was Lady Somerset, wife of the Lord Chamberlain. It is to be feared that her husband did not take sufficient care of his master's property!

incuse scrolls, the whole supported by a crystal figure of Pan kneeling. This object was brought from the summer palace of Pekin.[1]

5. A splendid variegated onyx ewer, cut out of a single pebble, set in gold with rubies and enamelled work. The ewer itself is of antique Roman date, while the mounting and adornment was added by an Italian artist in the sixteenth century. The ewer was taken at the sack of the summer palace of Pekin, and it may be well supposed that few works of art have undergone such strange vicissitudes. Originally formed by a Roman sculptor, probably before the Christian era, it descends through sixteen centuries or more, to be re-mounted and decorated with gems by an Italian worker in jewelry. It afterwards finds its way—who can tell by what strange changing of hands!—to China, and is deposited amongst the treasures of the monarch of the Celestial Empire. It is afterwards seized by a 'barbarian' army of invaders, carried back to Europe, and becomes the property of a British commoner.[2]

6. Jasper cup of triangular escalloped form, carved at the base with upright leaves; it has a stem and foot surrounded with two belts of painted enamel scroll and flowers. The cup is a work of the seventeenth century.

[1] It now belongs to the Duke of Buccleuch.

[2] Mr. T. M. Whitehead.

7. Large oval sardonyx bowl, carved out of a solid mass of rich, deeply shaded stone, with striped spots of a lighter shade. It is fluted inside, and on the outer surface has a series of vertical lines arched above. This large and noble pebble measures nearly ten inches in longer diameter, and is three and a quarter inches in height. It is mounted on a stem and foot of gold, chased and enamelled with cinquecento designs, supported by twelve upright bars with festoons between.[1]

8. The 'Cellini ewer' is cut in sardonyx; it is of a flattened oval form mounted in enamel, and adorned with gems taken from the crown jewels of France before the first revolution. These are described in detail in an inventory made by decree of the National Assembly in 1791; the ewer itself is a work of the sixteenth century.

A figure of Constantine the Great on horseback, brandishing his lance against his prostrate enemies; cut in sardonyx, and now in the cabinet of antiquities in the Royal Library deserves special notice.[2]

In the Galleria degli Uffizi at Florence, one of the chambers contains no less than 400 gems and works of art in precious stones, such as jasper, agate, chalcedony, rock-crystal, and lapis-lazuli, once the property of the Medici. Amongst these is a jug of rock-crystal

[1] The property of the Duke of Hamilton.

[2] Nouv. Manuel d'Archéol. par P. Nicard, 1842.

fourteen inches by eight, on a gold pedestal, by Benvenuto Cellini; two bas-reliefs in gold on a ground of jasper, and a large basin of lapis-lazuli about fifteen inches in diameter.

The art of sculpturing in jasper, agate, crystal, and aventurine is successfully practised in Russia, and several magnificent examples, in the form of vases, bowls, &c., were contributed to the Industrial Exhibition of 1851.[1] One of the finest works which has proceeded from that, or any other, country in modern times, is the polished vase formerly in the possession of the late Sir R. I. Murchison, and presented to him by the Emperor Nicholas I, in recognition of his services as 'the explorer of the geology of Russia.' This noble vase measures four feet in height, by six feet in circumference, and is supported by a pedestal of polished grey porphyry. The prevailing tint is pearl-grey, clouded with delicate rose-tints, and it is remarkable both for the beauty of the material, the elegance of its form, as well as for its excessive rarity; the difficulty of procuring a stone of such large dimensions, and of polishing so hard a substance being such that only one other similar vase has been made. This was presented to the late Baron Humboldt, and is now in the Royal Museum, Berlin.[2]

[1] The chief seats of this industry are the Imperial Polishing Manufactories of Perm and Tomsk.

[2] Bristow, Gloss. Min. p. 31.

With such examples we may be allowed to call in question Mr. Dana's statement that the artificial imitations of this stone are more beautiful than natural aventurine.[1]

[1] Man. Min. p. 134. Sir R. I. Murchison bequeathed the aventurine vase to the Museum of Practical Geology, London.

The name of this stone is sometimes written *avanturine;* but I have preferred to follow that which is suggested by the origin of the word as described above, p. 179.

PART IX.

CHAPTER I.

MALACHITE.

MALACHITE. (Molochites, *Pliny.*) This is one of the few metallic ores capable of being used with success for ornamental purposes in place of marble. It is a green carbonate of copper, and occurs essentially in a stalagmitic form, generally devoid of crystallization. It effervesces freely with heated nitric acid, and has a specific gravity of 3.57–3.68; hardness, 3.5–4.0. The composition varies, but the two following analyses will serve to give the general result:

	Klaproth.[1]		Phillips.
Copper	58.0	Protoxide of Copper	72.2
Oxygen	12.0		
Carbonic Acid	18.0		18.5
Water	12.0		9.3
	100.0		100.0

Malachite is a very handsome mineral when cut and polished; presenting various shades of apple to emerald green, and various degrees of translucency

[1] Brongniart, Traité de Min. p. 223.

down to complete opacity. The shades are arranged in globular concentric folds around a central nucleus, or in a wavy strata—the differently-shaded layers arranging themselves in accordance with the sinuosities of the adjoining layers. The mass is made up of fine globules, which often show a radio-concentric structure; and in most cases has been formed from a cupriferous solution which has successively deposited its residue in a stalagmitic form.[1] Concretionary malachite occurs in mammilated masses of undulating parallel beds, striated in the direction of their thickness, the surfaces of contact being often overspread with pulverulent malachite, or decorated with black dendrites, which have a very pretty effect on the greenish ground. The masses are rarely homogeneous and compact, often containing cavities which render the mineral unfit for ornamental use; but large masses free from such defects have occasionally been procured: one piece, especially cited, having been fashioned into a table eighty-five centimetres long, and forty-five broad.[2]

The largest masses of this ore of copper have been obtained from the Ural mountains; one of which is described by Murchison, and his companions in travel, as having been found at Nijni Tagilsk, occupying a fissure between schaalstein on the one side, and

[1] Murchison, Geol. of Russia, i. p. 374.
[2] Brongniart, Traité de Min. ii. 223.

Silurian limestone on the other; the upper surface presented an area of eighteen feet by nine, and penetrated to an unknown depth.[1] It is also obtained in Bohemia, Saxony, Hungary, and the Tyrol. In Britain it rarely occurs except in small quantities, associated with other ores in Cornwall, &c. From Australia, however, enormous masses of this ore have been obtained from the celebrated Burra-Burra mines, situated about ninety miles N.E. of Adelaide. These rich deposits of carbonate of copper resemble in their shallower portions the malachite formations of Russia. In a great basin formed in an amphitheatre of hills is an immense deposit of clay, resulting from the decomposition of the clay slate, of which the surrounding hills are formed. In this clay the deposit of malachite is found. There are some evidences which appear to show that the earliest condition of the mass was that of oxide and native copper; and that this has been changed into a carbonate, in all probability, by water charged with carbonic acid.[2] In the United States, it occurs at the copper mine of Cheshire, Conn.; also at Morgantown, Penn., and Schuyler's mine, New Brunswick.

[1] Murchison, Geology of Russia, i. 374. This mass has since been excavated in large blocks. See Catalogue, Exhibition 1851, art. 'Russia.'

[2] Descrip. Guide Mus. Prac. Geol. p. 95. The Burra-Burra mines were opened in 1845.

Art Illustrations. Ornamental and decorative works in malachite are peculiarly Russian, and the sculpturing is carried on with great success in that empire. Of this branch of art several magnificent examples were displayed at the Industrial Exhibition in London in 1851, and in subsequent international exhibitions. These works consist of large vases, tables, timepieces, fireplaces, and ornaments, of which there is a celebrated manufactory in St. Petersburg.[1] It is also advantageously employed for inlaying. At the palace of Versailles, there is (or was) a room furnished with tables, vases, and similar articles, all of malachite; it is also largely used in the palaces of royalty, both in Russia and other countries of Europe. One of the most beautiful of the malachite tables I have ever seen, stands in one of the chambers of the Galleria Pitti in Florence. It is six feet in length and was originally brought from Russia.

[1] That of Messrs. Demidoff, who were the chief exhibitors in 1851.

PART X.

CALCAREOUS GROUP OF BUILDING STONES.

CHAPTER I.

LIMESTONE.

Limestone of several varieties is largely employed as a building material. These varieties depend very much on differences of origin and composition, and correspond to successive geological periods. Amongst the oldest formations, limestones are comparatively rare, at least in the British Islands and Europe, and it is not till we ascend into the Devonian, and especially the Carboniferous periods, that they assume a high importance as compared with the other strata. From this period forwards into Tertiary times they are proportionately more fully developed, till amongst the Cretaceous and Lower Tertiary formations, they become the most conspicuous members.

This gradual augmentation in volume, as compared with the associated sedimentary strata consisting of various forms of sand or clay, appears to be intimately connected with the development of those classes of

marine animals which form for themselves calcareous shells or skeletons by the vital process of assimilation; by which the calcareous matter dissolved in the waters of the ocean by carbonic acid is seized upon, and converted into the stony skeletons of the inhabitants of the deep.

That all the great marine limestone formations have been derived either directly, or in a secondary manner, from organic agency is a view which is capable of demonstration, if we suppose that the proportion of carbonic acid in sea-water was as high in geologic times as in the present day. For Bischof[1] has shown that there is in existing seas about seven times as much of this acid as would be necessary to hold in solution the carbonate of lime contained therein; hence it could not be precipitated on the sea-bed in a solid state unless by vital forces. The composition also of the generality of marine limestones bears out this view of their origin. In the great majority of them remains of fossil shells, or internal skeletons, are visible to the eye, often in a fragmentary form. And even where this organic structure is not apparent, it does not follow that there has been no organic agency originally in operation; as the observations of Professor Jukes on the formation of coral reefs show that the organic structure of the reef is often obliterated during the very process of formation.[2]

[1] Chemical Geology, vol. iii. [2] Voyage of H.M.S. 'Fly.'

When we examine the characters of those animals which were the most industrious of the limestone-builders of the different geological periods, we find that they were, for the most part, of simple structure, and low organisation; for the higher forms of mollusca, such as the Cephalapoda and Gasteropoda, contributed but an inconsiderable share to the formation of limestones. The most important workers were *Foraminifera*, the *Polypi* (or coral-animals), the *Echinodermata* (including crinoids, starfish, and sea-urchins), the *Bryozoa*, together with the *Brachiopoda* amongst the mollusca; the remaining classes of the mollusca played a secondary part.

Taking a rapid survey of the great limestone deposits, from Silurian down to Tertiary times, we find that in each case the forms of life which were the most active agents in their formation were the following:—

Silurian and Devonian. Corals (*Zoantharia tabulata*, and *Z. rugosa*),[1] crinoids, and brachiopods.

Carboniferous. Corals (*Z. tabulata*, *Z. rugosa*, and *Z. tubulosa*), crinoids, and brachiopods.[2]

Permian. Corals (not abundant; *Z. tabulata*, and *Z. rugosa*), bryozoa, and conchifera.

[1] These groups of corals are here arranged according to the classification of Milne-Edwards and Haime.

[2] Some of the limestones of Scotland of this period are largely formed of the skeletons of entomostraca as shown by Mr. J. Young.

Jurassic, or *Oolitic*. Corals (*Z. aporosa*), foraminifera, echinoderms, bryozoa, and mollusca.

Cretaceous. Foraminifera, corals (*Z. aporosa, Z. tabulata, Z. rugosa*), bryozoa, and echinoderms.

Tertiary. Nummulite limestone, composed of skeletons of foraminifera, and of corals (*Z. aporosa, Z. perforata, Z. tabulata*).[1]

[1] Dr. T. Wright, on 'Coral Reefs Past and Present,' Trans. Cotteswold Nat. Club, 1866.

CHAPTER II.

BRITISH LIMESTONES.

THE limestones chiefly employed in the British Islands for building purposes are derived from the Carboniferous, Permian, and Oolitic formations. Those from the Purbeck and Wealden formations have already been described under the head of Marbles, as also those from Devonian rocks. We shall now examine these building stones in the ascending order above stated.

Carboniferous Limestone. This formation comprises the main portion of the lower division of the Carboniferous series; being the foundation on which has been reared that great superstructure of sedimentary deposits, including the Yoredale series, Millstone Grit, and Coal-measures, which in Lancashire attains the enormous thickness of 18,600 feet.[1]

In Derbyshire the limestone consists of very pure granular, or crystalline, carbonate of lime, of grey, blue, and (when dolomitic) of yellow colours; with

[1] E. Hull, 'Thickness of the Carboniferous Rocks, &c.,' Journ. Geol. Soc. Lond. xxiv. 322.

occasional lenticular bands of a siliceous stone called 'chert.' Its upper beds are dark, and produce black marble; some beds are reddish, and variegated. The whole mass attains a thickness estimated by the Government Geological Surveyors at 5000 feet, and appears to be composed of remains of corals, crinoids, and molluscs.[1]

Towards the North of England the Carboniferous limestone is split up into several separate layers, with intercalated beds of shale, sandstone, and coal,[2] which in Scotland assume a high degree of importance, giving rise to the Lower series of coal and ironstone measures; while the beds of limestone dwindle down to a few thin bands, chiefly useful for affording hydraulic lime and cement.[3]

Throughout this region, the Carboniferous limestone is rarely employed to any extent as a building stone; its chief use being for the manufacture of mortars, cements, marbles, and for fluxing iron-ore. As the grits and sandstones of the Millstone and Yoredale beds generally occur in the neighbourhood of the limestone, they are generally preferred as a material for building, for which they are better adapted.

[1] Hull, 'On the Distribution of the Carboniferous Strata, &c.,' Journ. Geol. Soc. Lond. xviii. 137. See also Horizontal Sections of the Geol. Survey, Sheet 42.

[2] Professor Phillips' Geology of Yorkshire.

[3] Such as the Arden limestone, near Paisley, and the Garnkirk, and Burdiehouse limestones near Coatbridge, and Edinburgh.

The Carboniferous limestone of Denbighshire and Flintshire is similar in appearance and composition to that of Derbyshire; its thickness varies from 1000 to 1500 feet, and it is extensively quarried for lime and cement. In the South-west of England it forms an encircling zone around the Somersetshire coal-basin, and rises into the table-land of the Mendip Hills. It also forms a similar zone round the margins of the South Wales and Forest of Dean coal-fields; and from its tendency to form mural cliffs and terraced escarpments, it produces, along the valleys of the Wye and the Avon, features at once bold and beautiful.

CHAPTER III.

MAGNESIAN LIMESTONE OF THE PERMIAN FORMATION.

This formation ranges in a nearly north and south direction through the North-east of England, from Tynemouth to Nottingham; disappearing, however, beneath the New Red Sandstone for a few miles in the neighbourhood of North Allerton; and generally forming the escarpment of an elevated plateau, overlooking towards the west the coal-fields of Durham, Yorkshire, Derbyshire, and Notts. The formation is interposed between the Carboniferous rocks below, and the Triassic rocks above, and is unconformable to both. Hence the Permian strata may be found resting in some parts on upper beds of the Coal-series; in others, on lower beds of the Millstone Grit; while, on the other hand, the New Red Sandstone rests on different members of the Permian series, or (as already observed) passes over and rests directly on Carboniferous strata.

The Magnesian Limestone series of Durham has a thickness of about 300 feet, and is overlaid by red marls with gypsum; it reposes in turn upon marl slate, and Lower Permian Sandstone, the whole series

attaining a thickness of about 600 feet.[1] In the neighbourhood of Mansfield the series consist of an upper and lower bed of Magnesian limestone, with intermediate marls and sandstones.[2] The lower limestone is the more important, attaining a thickness from seventy to one hundred feet; it is variable in quality, and at Mansfield passes into a white calcareous sandstone, with which the terrace in Trafalgar Square in London is paved. The following analysis, by the late Mr. Richard Phillips,[3] will give a general idea of the composition of this and the Mansfield 'red stone' which it strongly resembles except in colour.

White and red siliceous dolomites of Mansfield, Derbyshire.

	White.	Roseate.	Brown.
Silica	51.40	49.40	49.40
Carbonate of Lime	26.50	26.50	26.50
Carbonate of Magnesia	17.98	16.10	16.10
Iron, Alumina	1.32	3.20	3.20
Water and loss	2.80	4.80	4.80
	100.00	100.00	100.00

The stone from these quarries is largely employed in building and paving, as also for making troughs and cisterns. The excellence of the stone is testified on the high authority of Sir Gilbert Scott. In the

[1] According to the observations of Professors Sedgwick and King.

[2] W. F. Aveline, 'Geology of parts of Notts and Derbyshire,' Mem. Geol. Survey, p. 5.

[3] *Ibid.* p. 6.

direction of Nottingham the formation deteriorates, and passes into a friable calcareous sandstone.

The stone from the Mansfield Woodhouse quarries is a massive, but irregularly-bedded, crystalline limestone of a fine yellow colour, in some places speckled with black. It is hard and durable, as testified by the good condition of Southwell church, and it has been employed in the foundation and lower portions of the Houses of Parliament, and in the construction of the Martyrs' Memorial at Oxford.[1] The stone from Bolsover Moor quarries, nearly identical in geological position with that from Mansfield, was selected by the Commissioners for the New Houses of Parliament, but not used in the building. It is a yellowish-brown dolomite, compact and fine-grained, but variable in quality, and requiring careful selection. The stone from Anston quarries, Yorkshire, is of excellent quality, and has been used for the front of the Museum of Practical Geology, London, in which there is not a single bad block. The other important quarries of Magnesian limestone are situated at Brodsworth, Cadeby, and Park Nook near Doncaster, Huddlestone near Sherburne, and Smawse near Tadcaster, all in Yorkshire; while in Derbyshire the same stone is obtained at Bolsover, and in Notts at Mansfield Woodhouse, already referred to.

[1] W. F. Aveline, 'Geology of parts of Notts and Derbyshire,' Mem. Geol. Survey, p. 8.

The following are analyses of the Bolsover (I), and the Mansfield Woodhouse stones (II).

	I.	II.
Carbonate of Lime	51.10	51.65
Carbonate of Magnesia	40.20	42.60
Oxide of Iron and Alumina	1.80	trace
Silica	3.60	3.70
Water and loss	3.30	2.50
	100.00	100.45

The sp. gr. of a dry mass of the Bolsover stone is 2.316; the weight of a cube of two inches, 4890.8 grains in the ordinary state; when dried, 4881.4 grains; when saturated with water, 5042 grains;[1] one specimen from Cadeby absorbed one-fourth its bulk of water.

General Observations. From the above description and analysis, it will be seen that this rock is of variable quality and composition, the proportions of carbonate of lime, magnesia, and silica, rapidly varying and influencing the durability of the rock as a building stone. In general it may be affirmed that the dolomite of the north-east of England is more dense than the oolite limestones, and stronger than the Portland stone, but that it disintegrates rapidly in a smoky atmosphere; especially where deeply cut into mouldings, as those of the New Houses of Parliament unhappily evince. On the

[1] R. Hunt, Descrip. Guide M. P. G. p. 31.

other hand, the colour of the stone is pleasing to the eye; and if care be observed in the selection of the blocks in the quarry it will prove an excellent stone for architectural purposes, and for buildings erected beyond the influence of the smoke of towns.

Amongst the edifices constructed of Magnesian limestone which have well resisted the effects of time, may be mentioned the choir of Southwell church of the twelfth century; the stone is similar to that from Mansfield, being a siliceous dolomite, while the Anglo-Norman portions, built of a stone similar to that from Bolsover Moor, are in a very perfect state; the mouldings and carved work retaining the sharpness of the original sculpture.

The keep of Koningsburg Castle, built of Magnesian limestone from the vicinity, is in a perfect state, although the joints of the masonry are open in consequence of the disappearance of the mortar. Tickhill church of the fifteenth century, Huddlestone church of the same period, and Huddlestone Hall of the sixteenth century, are in a good state of preservation; and the stone of Roche Abbey of the thirteenth century is for the most part intact.

On the other hand, the churches and minster of York, Howden church, Doncaster old church, and others in that part of the country, all built of Magnesian limestone, have suffered severely from atmo-

spheric influences,—the mouldings having often been entirely effaced.[1]

The Commissioners appointed to report on the best building stone for the New Houses of Parliament concur in stating, that in proportion as the stone employed in Magnesian limestone buildings is crystalline does it appear to have resisted the decomposing effects of the atmosphere; and Professor Daniell observes that the nearer the composition of Magnesian limestones approaches to equivalent proportions of carbonate of lime and carbonate of magnesia, the more crystalline and better they are in every respect.[2]

[1] Report of the Building Stone Commission, 15th July, 1839. New edit. 1845. The Commissioners included Sir Charles Barry, Sir H. De la Beche, Mr. William Smith, and Mr. Chas. H. Smith, assisted by Professors Daniell and Wheatstone.

[2] *Ibid.*—These proportions are 45.7 per cent. carb. of magnesia and 54.3 of carb. of lime. Cotta (Rocks class. p. 245) proposes that all lime-stones containing upwards of 23 per cent. carb. of magnesia should be classed as dolomites.

CHAPTER IV.

OOLITIC, OR JURASSIC LIMESTONES.

THE Oolitic group of rocks lying above the great argillaceous formation of the Lias, yields varieties of building stones more largely in request, and better adapted, perhaps, for ordinary architectural purposes than any of the other British formations. This group of strata extends in a band of varying width from the coast of Dorset to that of Yorkshire; through Somersetshire, Gloucestershire, Oxfordshire, Northamptonshire, and Lincolnshire. North of the Humber it is gradually overlapped and concealed for a distance of fifteen miles by Cretaceous strata, but emerges again at New Walton, and rises into the higher escarpments of the Cleveland Hills.

Nature of the Limestones. The limestones of this group, though varying somewhat according to locality and geological position, are generally soft, uniform in texture, either white, cream-coloured, or yellow, and composed either of fragments of shells cemented by calcareous oolitic material, or of small grains, or ovules, of carbonate of lime firmly bound together. It is owing to this structure that the formation has received its name of 'Oolite,' but as

these strata are nobly developed in the picturesque range of the Jura, lying on the borders of France and Switzerland, geologists both of Britain and the Continent are now inclined to adopt the territorial name, 'Jurassic,' in preference to the petrological term, 'Oolitic,' when speaking of this series of strata.

Structure and Specialities. On examining a specimen of Bath or Cheltenham Oolite, we find that the spherular grains are either hollow, or contain as a nucleus a grain of sand, or a fragment of a shell, or other foreign substance. The size of other spherules is about that of the roe of a small fish; but in a few instances they are much larger.[1] Fragments, or whole shells, or skeletons of molluscs, crinoids, and corals are enclosed; and, not unfrequently, the strata present in a conspicuous degree the phenomena of oblique-lamination, arising from the action of currents in the waters in which they were deposited.

All these Oolitic limestones are of marine origin. They are composed of carbonate of lime, with various proportions of carbonate of magnesia, silica, alumina, and iron. When used for buildings not subjected to the smoke of cities and manufacturing towns, they often last for lengthened periods. But different beds have very different powers of resisting

[1] As in the case of the pisolite, at the base of the inferior oolite at Cheltenham. See 'Geology of the Country around Cheltenham,' Mem. Geol. Survey, p. 32 (1857).

the influence of the atmosphere; of which instances will be presently adduced. When first quarried it is often sufficiently soft to be cut with the saw; but hardens on exposure. This is the case both at Bath and at Cheltenham.

Geological Position of the best Building Stones. The Jurassic series contains four distinct formations of Oolitic limestone, some of which are divisible into distinct bands, with varying petrological characters. These, in ascending order, are (1) The Inferior Oolite; (2) The Great, or Bath, Oolite; (3) The Coralline Oolite, or Coral Rag; (4) The Portland limestone. A short description of each of these will now be given.

1. *Inferior Oolite.* This formation is more fully developed in the Cotteswold Hills in Gloucestershire than in any other part of England, attaining at Leckhampton Hill, near Cheltenham, a thickness of 264 ft., and furnishing two courses of a building stone which has probably been used in the construction of Gloucester Cathedral, the Abbey Church Tewkesbury, Sudeley Castle, and several of the ecclesiastical buildings which adorn the Vale of the Severn. From this spot as a centre, the freestones of the Inferior Oolite thin away towards the north, east, and south. The following is the section of the strata at Leckhampton Hill:—[1]

[1] E. Hull, 'Geol. of Cheltenham,' Mem. Geol. Survey, 1857.

		Feet.
'*Ragstone*'	A rough, shelly, oolitic limestone, not used for building	38
Upper Freestone	White or light yellow oolitic limestone, used for ordinary buildings	34
Oolite Marl	Soft chalky limestone and marl	7
Lower Freestone	Fine-grained, compact oolitic freestone, white or light yellow, used for building purposes	147
Pisolite, or *Pea Grit* ..	Largely oolitic, friable limestone, shelly and coralline, unfit for building purposes	38

The principal quarries are at Bourton, Broadway, Guiting, Stanway Hill, Cleve Cloud, Painswick Hill, Sheepscomb Hill, Syreford, Brockhampton, and Loughborough. The stone from Painswick is of specially fine quality, approaching in texture the celebrated Caen stone of Normandy. The presence of this Oolitic limestone has imparted a special character to the domestic architecture of the hilly districts as contrasted with that of the plains, which are formed of Lias clay, and in which brick houses set in wooden frame-works abound. Some of the farmsteads and manor houses of the Cotteswold Hills, as old as Henry VIII or Elizabeth, are good specimens of the style of the period, and are built exclusively of Oolitic limestone.

2. *Great* or *Bath Oolite.* This formation has a much more extensive range than the Inferior Oolite, from which it is separated by a clayey stratum, called 'Fuller's earth,' which is absent in Oxfordshire.

The Bath Oolite has an average thickness of 200 feet[1], and is divisible into two members or zones; the lower including the 'Stonesfield slate' and Oolitic freestones of Burford and Tainton; the upper being formed of a compact white, brittle, or chalky limestone, not suitable for architectural purposes, in Oxfordshire. The lower member, however, produces a white Oolitic freestone of excellent quality in this county. It has been used in the ecclesiastical buildings of the 13th, 14th, and 15th centuries, in the city of Oxford, which have stood the assaults of time better than the more modern buildings, erected in the last century, of Coralline Oolite, from the neighbouring quarries of Headington Hill; proving the care which the architects of those days exercised in the selection of building stone. This stone is quarried at Tainton Downs and Burford; and it has also been used in the building of Blenheim Palace,[2] and the interior of St. Paul's Cathedral.[3]

This Oolitic freestone, forming the 'lower zone' of the Great Oolite, in certain directions entirely alters its character, and at Stonesfield, and Sevenhampton Common, near Cheltenham, passes into flagstones

[1] E. Hull, 'On the S.E. thinning out of the Secondary Rocks,' Quart. Journ. Geol. Soc. Survey, xvi. 74.

[2] E. Hull, 'Geol. of Woodstock,' Mem. Geol. Survey, p. 16.

[3] Gwilt, Encyc. Arch. p. 468. The recent additions and restorations completed in Lambeth Palace in 1833, at a cost of £83,oco, are of Bath Stone.

and tiles, which have been largely worked for roofing purposes, but have now been generally superseded by the lighter and more durable slates from North Wales.

The most important quarries, however, are those situated along the range of the Somersetshire hills, at Stinchcombe, Minchinhampton near Stroud, Bathampton, and Bath Baynton near Box, Chippenham, and Doulting. The stone is here largely worked by tunnelling under ground, and is of a fine grain, compact, slightly shelly, and soft when first extracted, but afterwards hardens. In colour it is nearly white, passing into yellow; and is capable of receiving sculpturings to a degree of sharpness only surpassed by Caen stone. At Bathampton the upper beds for a depth of 30 feet appear to be chiefly worked.

From these quarries the stone for most of the beautiful ecclesiastical structures of the West of England has been extracted, including the Abbey Church at Bath, Glastonbury Abbey Church (11th century), and Wells Cathedral (12th to 15th centuries); all of which are in good preservation.[1] On the other hand, the church of St. Mary Redcliffe, Bristol, constructed of Inferior Oolite of Dundry Hill,[2] and, exposed to the smoky atmosphere of a

[1] The Oolitic limestone used in the interior of Christ Church Cathedral, Dublin, has all the appearance of Bath stone.

[2] Gwilt, Encyc. Arch. p. 471.

populous city, has suffered much from exfoliation of the stone, chiefly in the ornamental portions. The following is an analysis[1] of the average Bath stone from Box:—Carb. lime, 94.52, carb. mag., 2.50, iron and alumina, 1.20, water and loss, 1.78, bitumen, a trace.

The Great Oolite ranges throughout portions of Oxfordshire, Northamptonshire, and Lincolnshire, and is quarried for building purposes in several localities along its course. The principal quarries are at Barnac and Casterton, in Northamptonshire, producing a light brown, oolitic, shelly limestone, which has been largely employed in all the mediæval structures of Cambridgeshire, the Isle of Ely, and North Suffolk. It has stood remarkably well when care has been taken to select for the more exposed portions the less earthy varieties.[2]

The Kelton stone, from quarries near Stamford, is a rich cream-coloured Oolite; rather harder, and more uniform than the Barnac stone, and has been largely used in the numerous beautiful churches of Northamptonshire. It has been also used for the modern restorations of the Peterborough and Ely cathedrals, and in St. Dunstan's-in-the-East, London.[3]

[1] By Professors Wheatstone and Daniell. 'Report of Commissioners,' &c.

[2] G. B. Burnell, C.E., 'On Building Stones,' Journ. Soc. Arts, March, 1869.

[3] Gwilt, Encyc. Arch. p. 467. The range and character of these Oolitic formations in Central England have recently been admirably

Haydor, near Grantham, has produced an Oolite used in Lincoln Cathedral, Boston, Grantham, and Newark parish churches, Culverthorpe House, and Belvoir Castle. The stone is of a brownish cream-colour, and large blocks can be raised from the quarries.[1]

The Ancaster quarries, near Sleaford in Lincolnshire, produce compact, fine-grained, cream-coloured Oolite, largely employed in the churches of Lincolnshire, and in private residences, such as Wollaton Hall and Belvoir Castle; blocks from 3 to 5 tons may be raised from their beds. Its specific gravity is greater than that of the Barnac stone, and it is also more cohesive; in Lincolnshire and the Midland counties it has well stood the test of time, and is in good repute from its agreeable colour, and the ease with which it may be worked.[2]

2. *Coralline Oolite.* This formation has a comparatively limited range, being interrupted throughout a large section of its course from Dorset to Yorkshire. It ranges from Berkshire, along a series of calcareous hills, into Oxfordshire, and again recurs near Scarborough, forming some noble cliffs along the coast south of that town. It is seldom, however, that it

described and illustrated by Professor Phillips, F.R.S., in his work, 'The Geology of Oxford,' p. 141 *et seq.* (1871).

[1] Gwilt, Encyc. Arch. p. 466.

[2] G. B. Burnell, C.E., 'On Building Stones,' Journ. Soc. Arts, March, 1869.

produces a building material, as it is generally of too incoherent a nature for that purpose. The stone of this formation from Headington Hill, near Oxford, was unfortunately employed to a large extent in the building and restoration of the colleges and ecclesiastical structures of that city during the last and preceding centuries; and often laid with the bedding-surface outwards, in total disregard of the recognised principles to be observed in setting stones in masonry. The result has been, that these modern structures present lamentable examples of weathering; and are in striking contrast to those of more ancient date, built with a stone brought from a greater distance, but with far greater power of resisting decay.[1] The best example of the use of Headington stone is that of Wadham College, which had exceptional means of selecting material from the quarries.[2]

4. *Portland Stone.* The Portland limestone forms the uppermost member of the Jurassic series, and, like the lowest, is largely in request as a building material. Its uses, however, are somewhat different; for as the Inferior and Great Oolite seem especially adapted to receive the delicate chiselings of the Gothic styles, so the Portland limestone is employed to greatest advantage for the massive and more

[1] The stone from Tainton Downs from the Great Oolite formation, see *ante*, pp. 207–8.

[2] Professor Phillips, Geology of Oxford, p. 299.

uniform structures of classic and Italian architecture. Thus, while Portland limestone has been advantageously employed in the construction of St. Paul's Cathedral, the churches of the reign of Queen Anne, and the massive columns and portico of the Bank of Ireland, it would have been totally unsuited as a material for the restoration of Henry the VII's chapel in Westminster Abbey, or for the New Houses of Parliament; this is owing to peculiarities of texture which I shall now describe.

Texture and Composition. In composition the stone is a nearly pure carbonate of lime, containing 95 per cent. of this mineral, and 1 per cent. each of silica and carbonate of magnesia. It is superior to the Oolitic limestones in hardness and durability in the presence of a smoky atmosphere, and is also less absorbent of moisture; at the same time, its texture is far from uniform; it contains numerous large shells, and is not devoid of flaws, on which account it is unfitted for elaborate and delicate carvings.

The following is an analysis, by Professors Daniell and Wheatstone, of the average composition of Portland stone:—

	Per cent.	
Silica	1.20	When dry aborbs 8.86 per cent. of its weight of water.
Carbonate of lime	95.16	
Carbonate of magnesia	1.20	
Iron, alumina	0.50	
Water and loss	1.94	
	100.00	

This stone is obtained from numerous quarries in the Isle of Portland, near Weymouth.[1] The best stone is in the north-eastern part of the island, the worst in the opposite side; the section in different localities also varies, but the following will serve to give a general view of the succession of strata.[2]

Sections of Quarries in the Isle of Portland.

West side.	Feet.	East side.	Feet.
		1. Vegetable mould	1
2. *Stone brash* and two beds of Cap increased to..........	20	2. *Stone brash.* Cream-coloured limestone..................	3
		3. *Dirt bed.* Clay with vegetable remains	1
4. *Roach*, in one bed 4 feet thick, and 2 feet united to the *white bed*	6	4. *Cap.* Hard cream-coloured limestone and clay, in three layers	10
5. *White bed.* Marketable freestone	8	5. *White bed.* Marketable freestone	5
Layers of flint, &c., unsaleable	6	Parting of flinty material ..	2
6. Two beds of roach full of oyster-shells, replacing the *middle bed*	6	6. *Middle bed.* Marketable freestone	5
		Parting of shelly limestone .	2
7. *Third bed* of saleable stone, not equal to the *white bed* in quality..................	6	7. *Third bed* with few shells, best freestone, varying from	7–14
	52		43

History, and illustrations of Use. Previously to 1623 this stone does not appear to have attracted any attention; but from 1660 it has gradually grown into use. Inigo Jones restored a portion of

[1] The principal are 'Trade Quarry,' 'King Barrow East End,' 'Vernstreet,' 'Castle's,' 'Waycroft,' 'Gosling's,' and 'Grove' quarries.

[2] Conybeare and Phillips, Geol. of England and Wales, p. 173.

old St. Paul's, 'casing the outside, and adding a grand Corinthian portico to the west part, all of Portland stone.' St. Paul's Cathedral, and many of the churches in London erected in the reign of Queen Anne, were constructed of stone very superior to that now generally employed, as far as regards durability. The quarries from which this stone—used by Sir Christopher Wren—was obtained have long since been deserted; the only reason assigned being that the merchants find they cannot sell that stone on account of its being a little harder, and therefore more expensive to work.[1]

Amongst the other public structures in London built of Portland stone, may be mentioned, the old Westminster and Blackfriars bridges, the Custom House, opened in 1817, Goldsmith's Hall, the Reform Club, and the colossal statue, a copy of the Farnese Hercules sculptured by Mr. C. H. Smith, which stands in the hall of the Museum of Practical Geology, of which the original is in the Museum of Naples.

Portland Oolite has been largely employed in the more prominent portions of some of the finest buildings in the City of Dublin; amongst them are the columns and portico of the Bank of Ireland, formerly Parliament House, founded 1729, and com-

[1] Mr. R. Hunt, Descriptive Guide Museum of Practical Geology, p. 30.

pleted exactly ten years after; the Custom House, founded in 1781, also ten years in completion; the General Post Office, the Royal Exchange, the frontage and some of the buildings of Trinity College.[1]

Ireland, like Scotland, being deficient in those formations producing soft calcareous freestones agreeable to the eye, and fitted for fine sculpturing, has been obliged to have recourse to England and France for building stone of this quality. That this was done from very early times is shown by the example of Christ Church Cathedral, founded about the year 1038, and built in the Anglo-Norman style. The interior of this venerable structure, now undergoing restoration or rather reconstruction, is built of cream-coloured Oolitic limestone, which is apparently identical with that of the West of England. This view is corroborated by the opinion of Mr. Street, founded on peculiarities in the original plan of the building, that the original architect was an inhabitant of South Wales or the border counties of England. Oolitic stone, derived either from Normandy or England, was not uncommonly employed in Ireland, in structures of the 11th and 12th centuries.[2]

[1] For some information on the matter I am indebted to the Rev. Dr. Haughton, F.R.S.

[2] Mr. G. Wilkinson, M.R.I.A., Ancient Architecture of Ireland, pp. 84–5.

CHAPTER V.

CRETACEOUS LIMESTONE, OR CHALK.

THIS well-known formation is a finely granular white carbonate of lime, formed for the most part of the microscopic shells of foraminifera, or the calcareous mud derived therefrom. It also contains fossil shells of molluscs, starfishes, and echinoderms. The lower beds—consisting of the 'Chalk Marl,' and 'Lower Chalk,'—are devoid of layers of flint, which characterise the 'Upper Chalk,' and the whole formation attains a thickness of about 1000 feet.

Range of the Formation. The Chalk escarpment ranges from the coast of Dorset to the entrance of the Wash, producing one of the most striking physical features in England; consisting of a smooth, dry ridge, forming the margin of a table-land everywhere intersected by narrow valleys, often waterless and steep-sided. North of the Wash the same escarpment reappears, and, crossing the Humber near Kingston-on-Hull, terminates in the bold promontory of Flamborough Head. South of the valley of the Thames the Chalk-downs form a nearly oval

range, stretching from the cliffs of Dover westward into Hants, and again eastward to Beachy Head. The white cliffs of Kent and Sussex have given to England the old Norman name of 'Albion.'

Chalk as a Material for Building. Generally, throughout its range, the formation is much too soft, and liable to atmospheric waste to be used as a building stone. At the same time, the harder varieties were formerly sought after for this purpose over the South-east of England; and when protected by an outer coating of flint, or other durable material, have been found to last very well. The ruins of St. Pancras Priory, near Lewis, which have stood for 800 years, may be cited in illustration.[1] St. Alban's Abbey Church, the longest in the kingdom, and some of the older portions of Windsor Castle, are in part constructed of Totterntive stone, a hard band at the top of the Chalk Marl.[2]

[1] Dr. Mantell, Geology of the South-east of England.

[2] On the authority of Mr. W. Whitaker, F.G.S.

CHAPTER VI.

LIMESTONES OF IRELAND.

THE Carboniferous limestone occupies the greater part of the central plain of Ireland, and has been largely used both in the ancient and modern buildings of this region. It is divisible into three members. 1. Lower limestone; 2. Calp, a Middle limestone; 3. Upper limestone; the whole attaining a thickness from 2000 to 3000 feet. The marbles from this formation have already been described. As a building stone there is much variety. The lower and upper divisions produce a good, crystalline, greyish limestone, sometimes dolomitic, and in a few instances oolitic. This later variety occurs along the shores of Killala Bay; and has been used in the construction of the beautiful, but ruined, Abbey of Moyne, where the sharpness of the sculpturing is still retained.[1] The Calp, or Middle division, consists of dark carbonaceous or earthy grey limestone, alternating with beds of dark shale and chert, and is very irregular in the stratification. The Upper limestone resembles the lower, but is more evenly bedded and flaggy. These general

[1] Mr. G. Wilkinson, Anc. Arch. of Ireland, p. 37.

divisions are not capable of being recognised over the entire country.[1]

Limestone has been employed in some of the most ancient structures in Ireland, the details of which have been carefully collected and faithfully delineated by Mr. G. Wilkinson. Amongst these may be mentioned the Round Towers of Cashel, Clondalkin, Clones, Donoughmore, Fertagh, Kilrèe, Swords, Timahoe, and the Seven Churches. Many of these structures present, in the doorways or windows, excellent examples of the Norman mouldings and ornamentations belonging to a period anterior to the introduction of this style into England.[2] As regards the object for which the Round Towers were built, a visit to Italy has led me to adopt the view of those who consider them to have been campaniles, or belfries; their Italian representatives being such structures as the campaniles of Florence, and of Pisa, generally known by the name of the Leaning Tower of Pisa. Sandstone seems to have been the favourite material for the sculptured portions of ecclesiastical and monastic structures until the introduction of pointed architecture of the early English style, when limestone was more generally employed. The cathedral structures of Christ Church, and St. Patrick in

[1] According to the opinion of Professor Jukes.

[2] Mr. Wilkinson's views on this subject appear to me to solve a problem which has been a source of difficulty to archæologists.

Dublin, and of Kilkenny, Cashel, and Limerick present interesting examples of this transition period. Amongst the examples of domestic architecture of a past age is the ruined Castle of Trim, of huge proportions, and of the Norman style of construction. The walls are upwards of 13 feet thick, constructed of the limestone of the locality, roughly squared and coursed, but not dressed; sandstones being used in the angles of the openings and the arches, in accordance with the Norman practice of building.[1] Muckruss Abbey, standing by the Lakes of Killarney, displays some good examples of limestone sculpture. Limestone of a bluish tint has recently been employed with excellent effect in ecclesiastical structures in Dublin and its vicinity, when combined with granite, or Portland oolite, for the angles and mouldings of doors and windows. The dark-coloured beds from the 'Calp' are liable to rapid decay, and have a gloomy aspect.[2] In some localities, however, they yield a hydraulic lime, and were employed by the Shannon commissioners for this valuable species of mortar.

The ordinary limestone of Ireland weighs in average per cubic foot 170 lbs.; the extremes of weight being 159 and 180 lbs. The average weight

[1] Wilkinson, Anc. Arch. of Ireland, p. 117.

[2] As shown by the state of the walls of the Library of Trinity College, Dublin.

of water absorbed by immersion is one-fourth of a pound; the greatest being one-half a pound. The chalk of Antrim weighs 160 lbs. per cubic foot, and absorbs 3 lbs. of water; the impure shaly calp weighs 160 lbs., and absorbs from one to four pounds of water per cubic foot.

As compared with the Oolitic limestones of England, the Carboniferous limestone contrasts unfavourably as regards colour. It is also harder, and more expensive to work; and not so well adapted for receiving with facility the delicate mouldings and ornamental sculpturings of Gothic architecture. It is chiefly as a source for the production of marbles that the formation is to be valued in an architectural point of view, and as such has already been described.

The Chalk Formation. The Chalk is extensively developed around the basaltic plateau of County Antrim. It is very similar to the Upper Chalk of England, and contains numerous layers, and large sponge-like masses of flint. It is generally tolerably hard, but very brittle, and subject to atmospheric waste; on which account it is seldom or never used as a building stone, though largely quarried for lime.[1]

Scotland. This country is devoid of calcareous strata suitable for architectural purposes. The meagre representatives of the Carboniferous limestone are solely employed either for the manufacture of

[1] Sir R. Kane, Industrial Resources of Ireland, p. 277.

hydraulic or ordinary mortar, or for the smelting of iron-ores, and the stone is far too valuable for these purposes to be used as a building material. The principal limestone quarries are those of the Roman Camp Hill, Burdie House near Edinburgh, Garnkirk, Hurlet, and Arden near Glasgow.

In the Western Highlands there are occasional bands of crystalline limestones amongst the Lower Silurian strata, which might be used as marble of inferior quality.

CHAPTER VII.

CONTINENTAL LIMESTONES.

France and Belgium. The limestones belonging to that part of the Continent adjoining England, are analogous in composition, and in geological distribution, to those of England itself. They may be arranged under the following heads, from the earlier geological periods downwards: (*a*) those of the Silurian, and Devonian, (*b*) those of the Carboniferous, (*c*) those of the Triassic, (*d*) those of the Jurassic, (*e*) those of the Cretaceous, and (*f*) those of the Tertiary periods. Some account will now be given of each of them, as far as they bear upon the subject before us.

(*a*) The rocks of the Silurian, Devonian, and Carboniferous series occur chiefly in Brittany, and south of the Meuse. They are all conformably inclined to each other,[1] and contain limestones of grey, blue, or dark colour, sometimes magnesian, or becoming true dolomites. They are frequently employed for building purposes, and often produce marbles; and these of several varieties.

[1] Sir R. I. Murchison, Siluria, 4th edit. p. 407. Chateau, Tech. du Bâtiment, i. 129.

(*b*) The Carboniferous limestone, used largely in Belgium, comprehends two varieties: the compact grey, blue, or black variety, and the finely granular ('petit granite').[1] The former is largely quarried on the banks of the Meuse, and in the environs of Tournay; the quality is variable. The second variety is more highly prized as a building material. It is formed of the *débris* of shells, corals, and crinoids, and is both quarried and shaped with ease. It offers a great resistance to crushing force, and is not liable to be attacked either by frost or rain. It is worked in Belgium at the quarries of Soignies, Ecaussines, Arquesnes, Felny, and Ligny, &c.; and in France at the quarries of Lille.[2]

(*c*) The limestone of the Trias is called *Muschelkalk*, or *Calcaire Conchylien*. It is interposed between the *grès bigarré* below, and the *marnes irisées* above, in France and Germany, but is absent in Britain. It is a shelly limestone, compact, grey, greenish, or yellow, or variegated. It is well developed in Lorraine and other places, as Grasse and Toulon.

(*d*) The Jurassic formation of France produces a building stone unsurpassed by that of any country for purity of colour, fineness of texture, and fitness for receiving the most elaborate and delicate chiselings of ornate architecture. The Caen stone of Nor-

[1] Chateau, Tech. du Bâtiment, i. 129.
[2] *Ibid.* i. 130.

mandy stands in the same relation to architecture as Carrara marble does to sculpture. Both occupy the highest position as materials for their respective uses in art, and both have been valued from a remote, though not equally remote, antiquity.

Range of the Jurassic Formation. This formation stretches in a broad band along the western flanks of the Vosges mountains into Central France, passing by Nevers and Bourges to the borders of the Atlantic at La Rochelle.[1] From Poitiers a narrow band extends in a northerly direction to the British Channel at Caen in Normandy. Along the east of France these rocks compose the picturesque range of the Jura mountains, forming the rocky frontier of Switzerland.

The formation is interposed between the Liassic shales with their bluish earthy limestones below, and the Cretaceous rocks above. It includes similar divisions to those established in England, and designated by the English names only slightly modified by MM. D'Orbigny and Omalius D'Halloy. [2]It would, however, be impossible, within the limits of this work, to follow these in detail. We shall confine

[1] MM. Elie de Beaumont and Dufrenoy's Geological Map of France.

[2] Dr. S. Wright has shown how clearly the fossils of these different stages throughout the Oolites correspond in England, France, and Germany. 'On the Correlation of the Jurassic Rocks, &c.,' Trans. Cotteswold Naturalist Club, 1869.

our attention to a few of the localities producing the more valuable of the building stones.

Inferior Oolite (Etage Bajocien, D'Orb). The following are sections of this formation at Sainte-Honorine, Calvados, in Normandy; and at Niort, Deux Sèvres, given by M. D'Orbigny as typical sections of the formation as it occurs in France.[1]

Sainte-Honorine.	Niort.
(*d*) Blue limestone, compact, hard, full of ammonites and stems of trees. 1 mètre.	(*d*) Not stated.
(*c*) White limestone, oolitic (grenu), with fossil sponges, &c. 10–12 mètres.	(*c*) Limestone white as chalk, and of very fine texture, worked for building stone (freestone). Several mètres in thickness.
(*b*) Ferruginous oolite, characterised by numerous ammonites. 2 mètres.	(*b*) Yellow limestone, argillaceous, enclosing sponges.
(*a*) Thin band of earthy ironstone.	(*a*) Compact, very hard sandstone, with the same ammonites as (*b*) and (*d*) of Sainte-Honorine.

The above series are separated by a band of blue shale (corresponding to the Fuller's earth of England) from the overlying beds of the Great Oolite, now to be described.

Great, or *Bath*, *Oolite* (Etage Bathonien, D'Orb.) This is the formation which yields, at Ranville and Caen, the building stone of greatest excellence. It extends without interruption throughout the Department of Nièvre by Nevers, by Dun-le-Roi, to Lucy-le-Bois; also in the Côte-d'Or, the Saône-et-Loire, and Herault. It is found on both flanks of the Vosges;

[1] Cours élém. de Palæont. et Géol. ii. 483.

in the Department of the Meuse, at Montainville, and in that of the Aisne, at Éparcy. In Brittany it is especially developed; along the coast of Calvados we may follow the strata, without interruption, from the upper beds of Port-en-Bessin, by Saint Aubin, to Ranville. The thickness of the strata is considerable, from fifty to sixty mètres, and the formation varies much in character and composition. The beds most important as freestones are near the bottom; consisting of fine-grained, white limestone, glossy, and filled with fragments of crinoids. They are nearly horizontal, and the thickness is about eight mètres.[1] The following is a short account of the special qualities of different kinds of Caen stone.[2]

(1) Quarries of Caen, Allemagne, La Maladrerie, and Quilly. Very handsome limestone, and white; of good quality, fine-grained, and uniform in texture. This stone is employed for fine sculpture in Normandy, England, and the United States of America.

(2) Quarries of Villers-Canivet, Aubigny, and Cauvicourt. This stone is the purest and most esteemed.[3] It is largely exported, and weighs 150 lbs. per cubic foot.

[1] D'Orbigny, Cours élém. de Palæont. et Géol. ii. 496.

[2] Chateau, Tech. du Bâtiment, pp. 211–12.

[3] Mr. G. B. Burnell considers that it will not stand exposure; quoted by Gwilt, Encyc. Arch. p. 480. The mediæval buildings of Falaise, a town situated near the Aubigny quarries, are in a dilapidated condition.

(3) Quarries of Amblie, Fontaine, and Henri. This stone is used in hydraulic constructions of the country, but is not exported.

(4) Quarries of Ranville, Fontenay, and Aucrais. The Ranville stone is especially useful in structures exposed to moisture and rain, as it is practically non-absorbent. It weighs 142 lbs. per cubic foot; and is, therefore, the most dense, with the exception of the Aubigny stone, of all the Oolitic limestones of Caen.

Specialities and Illustrations. Caen stone resembles that of Bath and Cheltenham, but is finer in texture, rather lighter, weighing in general about 120 lbs. per cubic foot, generally non-oolitic, and only less white than chalk. It is supposed that the quarries worked several centuries ago yielded a stone more durable than that raised at the present day. These quarries were situated amongst the upper beds, which have a finer and more crystalline texture than those at present quarried for exportation.

It must be admitted, however, that the objections which have been urged against the employment of limestones of the granular varieties in exterior work, are also applicable to the beautiful calcareous freestones of Caen. They are sadly liable to decay from atmospheric causes, which are intensified if combined with the smoke of towns. The present condition of the elaborate Anglo-Norman decorations of the exterior of Canterbury Cathedral, built by 'William

of Sens,' succeeded by his pupil 'English William,' in the twelfth century, sufficiently attest the truth of this observation.[1] It is, however, eminently adapted for use in the interior of buildings; and no stone is more capable of being wrought into all those intricacies of ornamental art which the fancy of man can invent, or his hand can execute, when employed on designs of Gothic architecture.

The introduction of Caen stone into Britain is curiously interwoven with history. It was probably introduced shortly after the Norman Conquest, having been a favourite stone with the architects who followed the fortunes of William, duke of Normandy, and his successors. Its introduction into Ireland may have been of a still earlier period, corresponding to the introduction of Norman and Lombardian styles of architecture into that country.[2] In England, however, it was largely used in cathedrals and other buildings down to the middle of the fifteenth century (1448), when Normandy was lost to Britain; and it is only in modern times that its use has been revived. Of its use in the earlier periods, the Cathedral of Canterbury and Westminster Abbey may be cited as examples; and, amongst modern structures,

[1] Mr. William Whitaker, F.G.S., of the Geological Survey, informs me that the restorations now in progress are being executed with the same stone as that originally used.

[2] See *ante*, p. 220.

the new façade of Buckingham Palace, and Mr. Hope's mansion in Piccadilly.

Of the other quarries in France yielding Jurassic limestone the following may be mentioned :—Those of St Vivien, St. Vaisé, and St. Sorlin, near La Rochelle ; those of Bourges Montbart and Châtillon, near Bourges, Dijon; those of Brillon, Mont St. Marie, Villé, Issey, Enville, and Mecrin, near Bar-le-Duc. From these quarries the Military Hospital of Vincennes, the Hôtel de Louvre, the Church of Rosny, the Cathedral of Toul, and the Viaduct of Nogent-sur-Marne have been constructed.[1]

Portland Oolite (Portlandien D'Orb). Occurs round the Paris Basin ; though sometimes locally absent, owing to denudation previous to the deposition of the Cretaceous strata. It rests upon the Kimmeridge clay, and is composed generally of white compact fossiliferous limestone, often cavernous. It is largely quarried in the Pas-de-Calais, and at Hanòringhen. It occupies extensive tracts in the Department of La Meuse, Haute-Marne, L'Aube, L'Yonne, La Nièvre, and L'Oise.[2]

(*e*) *Chalk of France* (Terrains Crétacés). The Cretaceous rocks of France form a nearly oval ring round the Tertiary basin of Paris, dipping away gently from the circumference, towards the capital

[1] Chateau, Tech. du Bâtiment, ii. 222.

[2] D'Orbigny, Cours élém. de Palæont. et Géol. ii. 562.

as a centre. They consist of seven members,[1] corresponding generally to those of England. The formation also occurs in the South of France, and along the base of the Pyrenees.

Some of the lower beds, consisting of 'tuffeau,' and 'craie tuffeau,' more or less arenaceous, are sufficiently hard for ordinary building stone; but it is seldom that the Chalk itself can be used except for interior work of buildings.[2] In the valley of the Lower Seine, however, it is extensively used in the best buildings, as at Rouen, Vernon, and Louviers.[3] It is also quarried and extracted by tunnelling amongst the vine-clad hills at Sens, along the line of railway from Paris to Versailles, about seventy miles from the former city.

(*f*) *Tertiary Limestones of the Paris Basin.* The Tertiary series of the Basin of Paris includes varieties of strata, both of marine and freshwater origin, consisting of limestone, sandstone, gypsum, and lignite. Some of the marine limestones yield blocks of great size and thickness. In colour the stone has a pale yellowish tinge, admirably adapted for street architecture under a smokeless sky; and no

[1] D'Orbigny's Stages: 1, 'Néocomien;' 2, 'Aptien;' 3, 'Albien;' 4, 'Cénomanien;' 5, 'Turonien;' 6, 'Senonien;' and 7, 'Danien.' Cours élém. de Palæont. et Géol. ii. Fig. 393, p. 384.

[2] Chateau, Tech. du Bâtiment, ii. 132.

[3] G. B. Burnell, Journ. Soc. Arts, 1860.

one can fail to observe how much of the beauty of the noble public buildings, and scarcely less noble ranges of houses, in the principal streets of this queen of cities, is due to the chaste purity of the stone, and its capability of being employed either in massive structures, or in those of a more ornate character. These limestones also abound in the South of France, and most of the buildings of Marseilles, Montpelier, and Bordeaux, are constructed of these materials.

The Tertiary limestones have been largely quarried along both banks of the Seine for use in Parisian buildings; and the quarries situated along the line of the Northern Railway (Chemin de fer du Nord), about twenty miles out of Paris, are now being vigorously worked for the restoration of the buildings recently destroyed by the Commune. The large caverns left under portions of the city, after the extraction of the stone, are now used for the remains of the dead collected from the city churchyards, which formerly abounded. The gypsum quarries in the vicinity of Paris have already been described.[1]

[1] The following is the order of succession as given by Sir C. Lyell. LOWER EOCENE: Argile plastique et lignite. MIDDLE EOCENE: (*a*) Soissonnais sans, or lits coquilliers; (*b*) lower calcaire grossier; (*c*) middle and upper calcaire grossier; (*d*) grès de Beauchamp, or sables moyens; (*e*) calcaire siliceux; (*f*) gypseous series and calcaire lacustre moyen. UPPER EOCENE: Calcaire de la Beauce, and Grès de Fontainebleau. Man. Elem. Geol. 5th edit.

The beautiful city of Brussels is also constructed of Tertiary limestone; the materials for the more important structures having been brought from the vicinity of Lille.

Of similar materials are built the Louvre in Paris, the Cathedrals of Amiens and of Rouen, from quarries at Bonneleau and Vernon respectively. These limestones contain bands of siliceous material, and the consequence is that, the progress of decay being unequal, the siliceous bands project in various forms to the great disfigurement of the architecture. This decay generally takes place where the rain reaches the limestone indirectly, as underneath cornices, niches, and entablatures. Similar cases of unequal weathering have been observed in the cases of the Arc de Triomphe, the Cathedral of Notre Dame de Paris, and we may add that of Bristol; but in this case arising from the use in the same edifice of sandstone and limestone indiscriminately.

Prussia (Rhenish). Carboniferous limestone, like that of Namur, is quarried at Aix-la-Chapelle.

Würtemberg is very rich in building limestones, derived both from the Muschelkalk of Friederichsthal and Rottweil; the Jurassic limestones of Urspring,

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p. 223. The gypsum of Montmartre yielded those remains of extinct mammalia which the illustrious Cuvier has described in his great work, 'Ossements Fossiles.'

Arnegg, Schnaitheim (interior work); and the reddish and yellow marbles of Kirchheim and Zwiefalten. There are also the calcareous tufas of Geisslingen and Untertürkheim. The calcareous tuff of Würtemberg, of a yellow colour, is so soft as to be cut with the saw when just quarried, but upon exposure hardens, and is much sought after for the construction of arches, tunnels, towers, and fortifications.[1]

Spain. Limestones belonging to the Carboniferous, Jurassic, and Cretaceous formations are extensively developed in Spain. Madrid is chiefly built of a siliceous dolomite, termed Piedra de Colmenar, from the name of the district in which it is quarried.[2]

Italy. Limestones are largely developed amongst the Austrian Alps and the Apennines, belonging to the Jurassic, Cretaceous, and Lower Tertiary formations.[3] In some portions of this tract, as for instance opposite the bay of Spezia, and amongst the Alban and Volscian mountains, these rocks constitute the main mass of the range, and frequently produce marbles of considerable variety, some of which have already been described. Many of the buildings of

[1] Delesse, Matériaux de Construction de l'Exposition Universelle de 1855.

[2] As I am informed by Professor O'Reiley; an analysis of this stone is given by Dr. Sullivan in *Atlantis*, 1863.

[3] Sir R. I. Murchison, 'On the Geological Structure of the Alps, Apennines, &c.,' Journ. Geol. Soc. Lond., vol. v. Sir C. Lyell, Manual of Geology, 5th edit. p. 230.

Verona, Venice, Padua, and some of the towns of Tuscany, are largely constructed of limestones, such as the Nummulitic, which are capable of receiving a polish, and thus become 'marbles.'

Africa and Asia Minor. The great formation of Nummulite limestone occurs in full force in the north of Africa, as for example in Algeria and Morocco. It has been traced from Egypt, where it was largely quarried of old for the building of some of the pyramids, and notably the great Pyramid of Cheops (as stated by Herodotus), into Asia Minor.[1] Of this stone the ruins of Baalbec are formed; and it is also the building stone of Aleppo, and some of the cities of the Holy Land. The range of mountains between Aleppo and Antioch is largely composed of cream-coloured limestone containing Nummulites.[2] This wonderful formation has also been traced across Persia, through the Himalayas to the frontier of China.

[1] Lyell, Man. of Geol. 5th edit. p. 230.

[2] Specimens of this stone were shown to me by Mr. W. J. Maxwell, C.E., who was employed in 1870 on the survey for the Euphrates Valley Railway.

PART XI.

SANDSTONE GROUP OF BUILDING STONES.

CHAPTER I.

SILICEOUS FREESTONES.

Sandstein (*Germ.*) Grès (*Fr.*)

SANDSTONE, sometimes called 'freestone,' is very largely employed as a building material in some portions of the British Isles, especially the northern; and it possesses this advantage over limestones and dolomites, that it is better able to resist the chemical action of the smoky atmosphere of large towns. Some varieties, however, are, on the other hand, equally liable to the influence of atmospheric disintegration, depending very much on the nature of the cementing matter; and quite as much judgment is necessary in the selection at the quarry of a good and durable sandstone, as of any other kind of building material. Of the injurious effects produced by simple weathering on sandstones of inferior quality, the venerable cathedral and churches of Chester,

until recently restored, afforded a lamentable example.

Geological Formations. Sandstones for building, paving, and flagging purposes in the British Islands are chiefly derived from three great formations,—the Devonian or Old Red Sandstone, the Carboniferous, and the Triassic. These formations are largely developed in England, Ireland, and Scotland, and in a manner often highly advantageous to the growth of architecture. Sandstones of the Wealden formation of Kent and Sussex from the neighbourhood of Tunbridge Wells, Godstone, and Maidstone, have been, to some extent, used in London and its vicinity; but in durability they are inferior to those from the older formations.

Composition and Texture. Sandstones are composed of grains of quartz and other materials, of variable size, bound together by some cementing material such as silica, carbonate of lime, or oxide of iron; sometimes pressure, and a high terrestrial temperature, have been the chief agents in the consolidation of sandstones.

Along with the quartz-grains, which form the essential constituents of these rocks, other ingredients are often present in large proportions, such as flakes of mica, argillaceous matter, fragments of limestone, agate, or jasper, felspar, fossil shells, or wood.

When mica is abundant, and is distributed in

layers over the planes of bedding, the rock is called a *micaceous sandstone.* If carbonate of lime is abundant, it is a *calcareous sandstone;* and if the materials are composed of the *débris* of felspathic rocks (such as granite, gneiss, porphyry, or trap), the rock is termed a *felspathic sandstone.*

In texture, sandstones have extreme variations, from the impalpably fine-grained to the coarsest grit, in which the grains may reach the size of a pea, or small bean. On the other hand, when the rock is composed of distinct pebbles, rounded, or waterworn, and which may vary in size from that of a bean, to a diameter of three feet, it receives the name of a conglomerate, and passes beyond the limits assigned to a building stone. When the component fragments are angular, or nearly so, the rock becomes a breccia. Of the former, the Old Red conglomerate of Argyleshire offers the finest example; of the latter, the brecciated limestone of Alberbury in Shropshire, belonging to the Permian system, may be cited as one of the most remarkable illustrations in the British Isles.[1]

Sandstones are often highly porous, and are capable of absorbing large quantities of water, according to the degree of porosity. In the elaborate series of experiments undertaken by Mr. Wilkinson

[1] Murchison's Silurian System, p. 63. Hull's 'Triassic and Permian Rocks,' Mem. Geol. Survey, p. 21 (1869).

on sandstones from various parts of Ireland,[1] it was found that some specimens absorbed as much as 11 lbs. of water per cubic foot, while others scarcely imbibed as much as 1 lb. As a general result it may be assumed that sandstones of ordinary softness and porosity absorb from 5 to 6 lbs. of water per cubic foot. As regards crushing weight, Mr. Wilkinson found it to vary from 1680 lbs up to 14,600 lbs for a cubic inch; the most tenacious specimen being a white 'quartz-rock, open and porous, semi-granular,' from Muckish in Donegal.[2]

Similar experiments were made by the Commissioners for the selection of stone for the New Houses of Parliament,[3] and are given in the Appendix.

Chemical Analysis. The following are analyses of samples taken from some of the best-known quarries of sandstone; it is almost unnecessary to remark that no two specimens would give exactly the same results, but those here stated may be considered to represent a fair average description of the workable stone in each quarry.[4]

[1] Prac. Geol. and Arch. of Ireland. Tables of Experiments.

[2] *Ibid.*—This seems to have been a quartzite rather than a sandstone.

[3] Report (1839) Appendix D.

[4] Report (1839) Appendix C. The light-red, yellow, and white sandstones of the 'Lower Keuper' division of the New Red Sandstone of England, appear to have been strangely overlooked by the Commissioners.

Chemical Analysis of Sandstones.

	Craigleith.	Darley Dale (Stancliffe).	Heddon.	Kenton.	Mansfield (Lindley's Red).
Silica	98.3	96.40	95.1	93.1	49.4
Carb. lime	1.1	0.36	0.8	2.0	26.5
Carb. magnesia	0.0	0.0	0.0	0.0	16.1
Iron, alumina	0.6	1.30	2.3	4.4	3.2
Water and loss	0.0	1.94	1.8	0.5	4.8
	100.0	100.00	100.0	100.0	100.0

Colour. Sandstones are extremely variable in colour; having various shades of purple, red, brown, yellow, and grey passing into pure white. Sometimes these tints alternate, and produce variegated sandstones not uncommon in the Triassic, Permian, and Carboniferous formations both of Britain and Europe. The most widely distributed colouring agent is iron, often occurring in company with manganese; and there are very few sandstones entirely destitute of the former metal, either as a carbonate, protoxide, or sesquioxide. On the nature of the colouring matter, Mr. G. Maw has made some very interesting experiments, founded on the chemical analysis of differently-coloured portions of the same rock; and he arrived at the conclusion, that in the case of red, and reddish brown, the colour is due to the presence of iron in a state of anhydrous sesquioxide; in the case of yellow colours, to iron in the state of hydrous sesquioxide; and that the blue or grey tints are due to carbonate, or pro-

toxide of iron.[1] These colours either pervade the mass of the rock uniformly, or are distributed along the planes of bedding; but examples occur, chiefly amongst the Carboniferous rocks, of variegated colours, disposed in concentric rings, or envelopes; while we frequently observe in some portions of the New Red Sandstone, blotches of yellow or white in the midst of a rock otherwise uniformly of a red colour—due to the deoxidation of the iron at these places.

Forms of Stratification. Sandstones may be either massive, thin-bedded, lenticular, or flaggy, according to the conditions under which they have been formed. When massive, the rock is of uniform composition throughout a considerable vertical depth, and is then suited for the production of large blocks for foundations, engine beds, and piers; such blocks are to be obtained from the Millstone Grit of England and Wales. When thin-bedded, the original layers, or beds, are parted into strata of moderate thickness, often by bands of shale or micaceous laminæ; such strata produce stones for ordinary buildings, walls, and paving. When lenticular or wedge-shaped, the rock is seldom so uniform in texture as when the bedding is even, and the blocks are more difficult to shape, owing to the want of parallelism in the upper and lower surfaces. When flaggy, the strata split

[1] 'On the disposition of Iron in variegated strata,' Quart. Journ. Geol. Soc. xxiv. 355.

up into thin layers; a kind of bedding especially characteristic of laminated micaceous sandstones, such as are to be found amongst the Millstone Grit series of the North of England, and the Lower Keuper sandstones of the central counties.

Not unfrequently the surfaces of flaggy sandstones present the phenomena of ripple-markings, similar to those we may see on a flat sandy shore, over which a gentle current has drifted; and 'oblique lamination,' also due to current action, is of frequent occurrence amongst sandstones of nearly all geological periods.

In laying courses of masonry care is necessary that the stone be placed in the same manner in which it was originally deposited; in other words, that the laminæ occupy a horizontal position. Otherwise, the atmosphere acting with greatest effect along the planes of lamination, the stone will flake off along the face of the building. Many instances might be cited where disregard of this evident rule has been attended with destructive consequences.

CHAPTER II.

SECTION I.

SANDSTONES OF ENGLAND AND WALES.

THE building sandstones of England are abundant, and sometimes of excellent quality, and are principally distributed throughout the central and northern counties. A brief account of the more important, arranged according to their geological position, will now be given. It seems unnecessary to refer specially to the great sandstone beds of the Cambrian and Silurian formations of Wales and Shropshire, as they are not employed, except locally, for building purposes.

(*a*) *Old Red Sandstone.* (Devonian.) The sandstones of this system have not been much employed for buildings of a higher class, with the exception of Tintern Abbey, an edifice of the 13th century, part of the stone of which is in good preservation.[1] They are distributed throughout parts of Devonshire, Herefordshire, and Monmouthshire. In colour they vary from deep red, or purple, through shades of green, yellow, and grey, to almost white; and though largely used for local buildings, are not at

[1] Built of stone from 'Barbadoes Quarry,' in the vicinity. Gwilt, Encyc. Arch. p. 459.

present in request for finer architectural purposes at a distance. In Devonshire building sandstones occur at the Hangman Hills, the Foreland, North Hill, Newnham Park; as also in the vicinity of Liskeard, and of Bodmin in Cornwall.[1]

North of the Severn the sandstone has been quarried in the neighbourhood of Chepstow, Monmouth, and Ledbury. Those portions of Chepstow Castle, of the 11th and 12th centuries, constructed of red sandstone of this formation, are generally much decomposed; while the remaining portions, built of Carboniferous limestone, are in a state of good preservation.[2]

(*b*) *Carboniferous Series.* The building sandstones of this group are referable to the Yoredale Beds, the Millstone Grit, and the Coal-measures. They occupy large tracts of the North of England, extending from Derby into the high moorlands of Yorkshire and Lancashire, being thrown off on either side from the great anticlinal axis of the Pennine Chain. The building stones of the Millstone series occur either as coarse massive grits, finer siliceous grits, or flaggy sandstones, suitable respectively for foundations, bridges, piers, engine beds, ordinary building stones, paving, and flagging. The stone is generally hard, durable, and of greyish or light

[1] De la Beche, Geol. Rep. p. 490.

[2] Report of Commis. Build. Stones, p. 21, Table B.

brown colours, and is used in many of the towns and villages of the North of England to a large extent, such as Manchester, Bolton-le-Moors, Blackburn, Haslingden, Burnley, Skipton, Bradford, Sheffield, and Leeds. The stone is admirably adapted for resisting the effects of the smoky atmosphere of these large manufacturing towns, as very little lime enters into its composition.

Flagstones of the Lower Coal-measures. Immediately over the Millstone Grit there occurs in Lancashire, Derbyshire, and Yorkshire, a series of strata, varying from 1000 to 2000 feet in thickness, known as the 'Lower Coal-measures' or 'Gannister Beds,'[1] which produces excellent flagstones, generally micaceous, evenly bedded, and parted by bands of shale. These are largely worked in some parts of the country, as at Whiston near St. Helens, Orrell, Billinge and Up-Holland near Wigan, Bradshaw near Bolton, at Rochdale and Oldham, at Kerridge and Shrigley near Macclesfield, and Wingfield Manor in Derbyshire. These flagstones are also largely quarried along the margin of the Yorkshire coal-field throughout a semicircular range of hills, from the valley of the Aire, near Leeds, by Bradford, Halifax, Hudders-

[1] A name given by Mr. E. W. Binney, F.R.S., and Professor Phillips to the series of the Lower Coal-measures, from the peculiarly hard siliceous rock, which forms the floor of the principal coal-seam. See Phillips' Manual of Geology, pp. 183–5 (1855).

field, and Peniston, to Sheffield; and from these quarries both the internal demand of the country, and that of the eastern and southern coasts is supplied.

(c) *Coal-measures.* The sandstones of the Coal-measures, on the other hand, are generally of a more destructible nature, containing as they do more argillaceous matter, as well as iron, than is the case with those just described. They are also rather softer, generally of purple, yellow, or greyish colours, and are very apt upon exposure to become iron-stained. The Pennant Grit sandstones, however, of Somersetshire and South Wales, occupying a central position in the Coal-series, 1500 to 3200 feet in thickness, more nearly resemble those of the Millstone Grit.[1]

SECTION II.

EXAMPLES AND ARCHITECTURAL ILLUSTRATIONS.

Out of the vast number of quarries scattered over the country formed of Carboniferous rocks, it will be impossible to do more than give a selection of the most important.

Quarries in Carboniferous Sandstones.

1. *Bakewell Edge*, Derbyshire. Yoredale Grit; a very handsome stone, of which the fronts of Chats-

[1] De la Beche, 'On the Formation of Rocks of South Wales, &c.,' Mem. Geol. Survey, vol. i. Hull, Coal-fields of Great Britain, 2nd edit. pp. 69, 80.

worth, Bakewell Church, and the Crescent at Buxton are built.[1] These rocks sometimes assume the appearance of ornamental wood.[2]

2. *Bolton's Quarry,* Aislaby, Yorkshire. Warm light-brown, moderately fine siliceous grit, micaceous, with specks of carbon, used in Whitby Abbey, New University Library, Cambridge; Scarborough Pier, and St. Catherine's Docks.

3. *Duffield Bank,* Derbyshire. Millstone Grit; dark and light-brown, or white, quartzose sandstone. This stone has been used in the construction of the Grammar School, Birmingham; and some of the public buildings in Derby.

4. *Elland Edge,* Yorkshire. Fine micaceous grit and flagstone of a light greyish-brown colour, slightly micaceous; worked for paving, flags, and building. From the Gannister Beds, or Lower Coal-measures.

5. *Gatherly Moor,* Yorkshire. Cream-coloured micaceous sandstone, moderately fine-grained, and sometimes obliquely laminated, and in thick beds; used in Aste Hall, Richmond, Purse Bridge over the Tees, Skelton Castle, and Darlington Town-hall.

6. *Harrock Hill,* Lancashire. Coarse-grained massive grit, grey and yellow in colour, about one

[1] Geol. of parts of Derbyshire and Yorkshire, by Messrs. Green, Foster, and Dakyn, Mem. Geol. Survey, p. 88 (1869).

[2] Report of Commis. Build. Stones. Table A.

hundred feet thick; quarried for paving, millstones, engine beds, and foundation stones.

7. *Haslingden*, Lancashire. Greyish micaceous flagstones, belonging to the Millstone Grit series. Numerous quarries in the neighbourhood producing flagstones and ashlar.

8. *Heddon*, near Newcastle-on-Tyne. Light-brown Coal-measure sandstone, spotted with oxide of iron, mixed with laminations of carbonaceous matter; used in Heddon Church, and buildings at Newcastle.

9. *Kenton*, near Newcastle-on-Tyne. Light-brown ferruginous sandstone, which can be raised in large blocks; used in modern buildings at Newcastle.

10. *Knockley*, Nag's Head, &c., Forest of Dean, Gloucestershire. Grey, micaceous sandstone from the Coal-measures, or Millstone Grit; used in the New Pier at Cardiff, and for troughs, grindstones, &c.

11. *Leeds*, Yorkshire. Coarse-grained massive greyish grit of the Millstone series, yielding blocks of large size for foundations, piers, and buildings.

12. *Longridge Fell*, Lancashire. Yellowish and greyish sandstone, not very coarse-grained. Worked along a system of joints, and of about 550 feet in total thickness. The rock belongs to the Yoredale series of the Carboniferous system, and is opened out in six quarries, some of which show a section of one hundred feet in depth. The stone weathers well, and has been largely employed in the churches and

public buildings of North Lancashire, amongst which Preston Town-hall may be mentioned.[1]

13. *Meanwood*, Leeds. Coarse-grained, light-brown, micaceous grit, yielding blocks up to 8 or 9 tons.

14. *Osmotherley*, Yorkshire. Dark-brown sandstone, moderately fine; formerly worked for railway chairs.

15. *Parbold*, Lancashire. Coarse-grained massive grit from the Millstone series, yielding large blocks.

16. *Peniston*, Yorkshire. Greyish and light-yellow flagstones, sometimes rippled and micaceous. Several other quarries of these flags are in the neighbourhood of Sheffield, Elland, and Bradford.

17. *Up-Holland, Billinge Hill*, Lancashire. Fine-grained micaceous flagstone, largely quarried for flags and paving stones, which are sent to Wigan, Liverpool, Preston, and all parts.

18. *Scotgate Head*, Huddersfield. Light-greenish grey, thin-bedded sandstone, used in York Castle, and Bath Hotel, Huddersfield.

19. *Stancliffe* and *Darley Dale*, Derbyshire. Light-yellowish brown, micaceous, moderately fine sandstone; used in the construction of Darley Abbey, Stancliffe Hall, Birmingham Grammar School, and numerous other buildings.

20. *Stenton*, Durham. Light yellowish brown grit, in beds from two to eight feet thick, yielding large

[1] For these details I am indebted to Mr. De Rance, of the Geological Survey.

blocks; used in the round keep of Barnard Castle, and modern buildings in the town of Barnard Castle.

21. *Stanningley*, Yorkshire. Light-brown fine-grained sandstone, suitable for steps, landings, and fine work, such as pinnacles, &c.

22. *Viney Hill*, Gloucestershire. Fine-grained purple and grey sandstone, used in the New Pier, Cardiff.

23. *Wheatwood*, Addingley, Yorkshire. Medium grained light-brown sandstone, and strong coarse grit, yielding large blocks; used in parts of Whitby Abbey, Sleights Bridge; the New Library, Cambridge; Town-hall, Whitby, and Market House, Exeter.

(*d*) Permian Sandstones. In the midland counties and Shropshire the Lower Permian formation consists of purple, reddish, or brown, speckled sandstone, interstratified with red marls, breccias, and calcareous conglomerates; but the sandstones are seldom of sufficient consistency or uniformity of texture to be useful for any but common buildings, and the colour is decidedly objectionable.

In Lancashire, Yorkshire, and Durham this formation consists of very soft bright-red and variegated sandstone, only fit for foundry purposes; but where it occurs in the valley of the Eden, and along the cliffs of St. Bees Head, it is rather firmer in texture, and has been almost exclusively used for buildings in the pretty town of Penrith, including the church and ruined castle. An examination of the older

portions of these structures will, however, be sufficient to show that it is not a durable stone, though sufficiently well suited for ordinary houses, walls, and cottages. Professor Harkness regards the Penrith sandstone as the lower, and the St. Bees sandstone as the upper, member of the Permian series of the North of England.[1]

Of these sandstones the beautiful ruined abbeys of Calder and Furness have been built, a careful selection of the stone having been the chief cause of their state of partial preservation.

(*e*) Triassic, or New Red Sandstone Series. The building stones belonging to this formation are widely distributed over the central and north-western counties, and are obtained both from the Bunter and Keuper divisions; but chiefly from the latter, and only in Cheshire and Lancashire.

Bunter Sandstone. This forms the lower division of the Trias in England, and consists, when in its complete form, of three members:—

3. Upper Red and Mottled sandstone.
2. Pebble beds, and conglomerate.
1. Lower Red and Mottled sandstone.

Of these, the upper and lower members consist of soft, fine-grained, red or mottled sandstone, unfitted

[1] Journ. Geol. Soc. Lond. xviii. 105, and xx. 144. The sandstone of St. Bees Head is described as stony and hard, of reddish-brown, whitish, and yellowish colours, p. 158.

for building purposes, and chiefly useful as moulding sand for foundries.

The middle member, throughout the central counties, consists of dull red, coarse, pebbly sandstone, passing into quartzose conglomerate, and is only fit for very rough and second class work, such as walls for fields, gardens, or cottages. When traced into West Cheshire and Lancashire, however, it becomes less pebbly, and assumes a more compact structure, so that it is capable of yielding a very fair building material of a light reddish colour, sometimes variegated with light yellow or grey bands, and is largely quarried at Liverpool, for buildings in that town and the vicinity; these quarries are situated along the eastern side, from Walton to Æverton, Kirkdale, and West Derby. There are also quarries at Roby, Hale, and Woolton.[1]

Lower Keuper Sandstone. This division of the Trias, lying at the base of the red marl, and above the Bunter sandstone, produces the best building material for the nobler kinds of architecture of the central counties, combining lightness of colour with durability, and fineness of grain with uniformity of texture. The general succession of these beds below the Keuper marl in Cheshire, Staffordshire, and Worcestershire, is as follows[2]:—

[1] Hull, on 'The Triassic and Permian Rocks,' Mem. Geol. Survey, p. 58 (1869).

[2] *Ibid.* p. 66.

General Section of the Lower Keuper Sandstone.

1. *Waterstones,* (passage beds into the red marl). Brownish laminated, micaceous sandstones and flags, rippled, with beds of sandy marl or shale.

2. *Building Stones.* Fine-grained, light-red, brown, yellow, or white freestones, regularly bedded, with occasional bands of marl or shale. In Cheshire and Worcestershire these occur at the base of soft red sandstone which underlies the 'Waterstones.'

3. *Basement Beds.* Coarse, irregularly-bedded, pebbly sandstones, calcareous breccia, and conglomerate with bands of marl and brecciated limestone (corn-stones).

This group of strata ranges from the estuary of the Severn northwards along the eastern base of the Malvern and Abberly Hills, to the banks of the Stour at Stourport. Throughout the midland counties it follows the margin of the red marl, and in Shropshire, Derbyshire, and Cheshire, often rises into remarkably picturesque escarpments or groups of scarped hills, such as those of Penn, Oreton, and Tattenhall, near Wolverhampton; the Hawkstone and Grinshill Hills, near Shrewsbury, the Peckforton, Delamere, and Frodsham Hills in Cheshire; and the Alton, Ramshor, and Okeover Hills on the borders of Stafford and Derbyshire.[1] The stone has

[1] The structure of these ranges of hills has been worked out by the Government Geological Surveyors, and is shown on the maps

been largely employed in the construction of many of the churches and mansions of the midland counties, and more recently in their restoration. Its fitness for use in the nobler ecclesiastical structures may be illustrated in the cases of Worcester and Chester cathedrals; the latter of which, renovated under the judicious superintendence of Sir Gilbert Scott will be more beautiful than it ever was before. Out of the large numbers of quarries in this subformation scattered over the country, the following deserve special mention:—

Chief Quarries of the Lower Keuper Sandstone.

1. *Belton, Muxton,* near Market Drayton, Salop. White and light red compact sandstone.

2. *Bidston Hill,* Cheshire. Light yellow and white freestone of good quality.

3. *Colwich,* Staffordshire. White, rather soft freestone, used in churches and mansions of the vicinity.

4. *Colton Mill,* Rugeley. White, soft, compact freestone, suited for finer kinds of architecture.

5. *Crumpwood,* Alton, Staffordshire. White freestone of good quality, yielding large blocks, similar to that used at Alton Towers.

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and sections of the Survey. A description of the strata will be found in the Memoir on the Triassic and Permian Rocks, pp. 67–97.

6. *Fulford*, near Cheadle, Staffordshire. Light brown sandstone.

7. *Grinshill*, near Shrewsbury. White, light yellow, and reddish brown freestone; flaggy at the top, with courses of massive stone yielding large blocks, presenting altogether a section of nearly 100 feet.[1] A stone well adapted for highest kinds of architectural work.

8. *Grug Hill*, Baschurch, Salop. Rather soft, fine, white sandstone, in lenticular beds.

9. *Helsby*, Delamere Forest. Light red, fine-grained, sometimes flaggy sandstone.

10. *Hollington*, Uttoxeter, Staffordshire. Light brownish grey, to white, freestone, fine grained, yielding blocks from 30 to 40 feet square, and 8 feet thick; used in Trentham Hall, Drayton Manor, Heath House, Town-hall, Derby, and Meer Hall, Cheshire.

11. *Manley*, near Dunham, Cheshire. White and light red freestone of good quality, and yielding large blocks. With the light-reddish freestone from this locality Chester Cathedral is now being restored.

12. *New Brighton*, Wallasey, Cheshire. Yellowish freestone, rather soft and fine grained.

13. *Ombersley and Hadley*, near Worcester. Red-

[1] A section of this quarry is given by Sir R. Murchison in the Silurian System, p. 40.

dish, light brown, and white freestone of good quality, thin-bedded in the upper part, massive below. Worcester Cathedral is now being restored with stone from these quarries.

14. *Oreton Hill*, near Wolverhampton. White and light brown freestone.

15. *Overton Scar*, Edge Hill, Chester. White freestone.

16. *Park Quarry*, Tixall, Staffordshire. Light brown, or grey sandstone, sometimes micaceous, in beds from 4 to 8 feet thick; used in old mansions at Tixall, Tixall Hall, St. George's Church, Birmingham, Sandwell Hall, Staffordshire.

17. *Peckforton*, Cheshire. Massive light red sandstone, durable, rather hard; used in the construction of Peckforton Castle. A similar material is used in Beeston Castle, now a ruin.

18. *Stanton*, near Ashbourn. White and light red freestone, similar to that of Hollington.

19. *Tixall* and *Weston*, Rugeley, Staffordshire. Light brown, compact sandstone; sometimes micaceous.

20. *Weston*, near Shrewsbury. White and light grey sandstone.

21. *Weston Cliff*, Donington Park, near Derby. White and light brown sandstone.

22. *Woodhead*, near Cheadle, Staffordshire. Light brown sandstone.

Sandstones of Formations newer than the Trias. With the exception of the sandstones belonging to the Lower Oolite formations of Yorkshire, the Wealden, and the Kentish Rag of the Lower Greensand formations, there are no sandstones of any importance overlying the Trias in England; and even these just named are only local and comparatively unimportant.

(*f*) *The Yorkshire Jurassic Sandstones*, containing bands of coal and jet, are considered by Professor Phillips as the littoral representatives of the marine limestones of the centre and south of England.[1] They are finely displayed in the sea-cliffs of Gristhorpe, Scarborough, and along Stainton Dale, and Haiburn Wylie; interstratified with shales, ironstones, coal, and ferruginous or calcareous bands. The stone has been largely worked at Aislaby, near Whitby, where it is of a light brown colour, moderately fine grain, and can be extracted in large blocks.[2] It has been used in Whitby Abbey, New University Library, Cambridge, and Scarborough and Bridlington Piers.

Tunbridge Wells Sandstone. This rock is included in the lower division of the great Wealden group, lying at the base of the Cretaceous system, and consisting of the following members :—[3]

[1] Manual of Geol. p. 297.

[2] Report of Commis. Table A.

[3] Mr. Drew, Mem. Geol. Survey (1833).

		Feet.
	5. Weald clay, with some local beds of stone	600
Hastings Sands.	4. Tunbridge Wells sand, with 'Grinstead clay'	150 to 200
	3. Wadhurst clay, with ironstone	100 „ 160
	2. Ashdown sand, with bands of clay and ironstone	160 „ 250
	1. Ashburnham beds, clays and sandstones (over)	330

The sandstone is quarried at Calverley quarry near Tunbridge Wells. It is fine-grained, with a slightly calcareous cement, and of a variegated brown colour. The beds vary from 1 to 3½ feet in thickness, and can yield blocks from 80 to 500 cubic feet. It has been used in the new church, Roman Catholic chapel, and other buildings at Tunbridge Wells.[1]

(*g*) *Kentish Rag.* The stone known by this name forms a portion of the Lower Greensand group, and may be best observed at Hythe and Folkestone, on the coast of Kent.[2] The stone is variable in character; and may be described as a calcareous sandstone, of a brown or light yellow colour, and often shelly. It is quarried at Godstone, Maidstone, Boughton, and the vicinity of Folkestone, and is used to a considerable extent in the more recent 'gothic' churches of London and the neighbourhood, as I am informed by Mr. W. Whitaker. The sandstones (or 'firestones') are however ill adapted to resist alternations of wet and dry

[1] Report of Commis. Table A.

[2] See Memoir on sheet 4 of the Geological Survey, by Mr. F. Drew (1864). The name given to this formation by Dr. Mantell was 'Shanklin Sand,' Geol. South-East of England (1833).

weather, nor are they suitable for internal work, as they are apt to 'sweat.' When used for building they require to be kept above ground, and also to be protected from rain. If these precautions are observed, these stones do not rapidly decay, and in some of the oldest parts of Westminster Abbey and the Temple Church, specimens of them may be observed in a fair state of preservation.[1]

[1] Mr. Burnell, C.E., Journ. Soc. Arts, 1860. See also Gwilt, Encyc. Arch. p. 564.

CHAPTER III.

SANDSTONES OF SCOTLAND.

THE chief sources of building sandstones in Scotland are the Old Red and the Carboniferous formations, which are largely developed between the Cheviot Hills and the Grampians, and yield some excellent building freestones, as well as others, suitable for flags and paving. The grits and conglomerates referable to the Silurian period require no special mention.

(*a*) *Old Red Sandstone.* This formation has been divided by Professor Geikie into three members, the central one of which is unconformable to the other two, while the lower graduates into the Upper Silurian rocks of Lesmahagow, and the upper into the Carboniferous series.[1] The lowest division[2] includes the grey sandstones and paving stones of Dundee and Arbroath in Forfarshire, much used in the streets of Edinburgh, Glasgow, London, and other large towns.[3] The middle division comprehends the

[1] Siluria, 4th edit. p. 250.

[2] To the north and south of the Clyde basin it consists of chocolate-coloured sandstones, and boulder conglomerates.

[3] In these flagstones, the remarkable featherlike thoracic appendages of a huge crustacean, called by the quarrymen 'Seraphim,

flagstones of Caithness, Cromarty, and Nairn; and the upper, the yellow sandstones of Dura Den, remarkable for the abundance of fish remains.

In reference to the use of these sandstones for building purposes, Mr. Burnell observes as follows: The Dundee and Arbroath stones are sometimes employed in London, the former as an ordinary building stone, the latter principally as a flag-pavement. The colour of the Dundee stone hitherto brought to London is rather disagreeable, for it is of a dark brown colour, or of a deep oxide of iron tint; but the stone is hard, and resists weather very satisfactorily; in consequence of the colour, however, this material is never used in ornamental buildings. The Arbroath stone is of a denser character than that obtained from Dundee, but it is more decidedly 'flakey,' to use a workman's phrase, and it is therefore almost exclusively used for the purpose above mentioned. Occasionally, however, blocks of the largest dimensions, and of a very uniform character, are obtained from the Arbroath quarries. They are hard; they resist weather satisfactorily; the stone is easily worked, and its colour (a light greenish grey) is far from being disagreeable.[1]

were discovered by the late Mr. Hugh Miller, and referred to their true origin by Prof. Agassiz. The crustacean is known as *Pterygotus Anglicus*, Ag. 'Poissons fossiles,' &c.

[1] *Ibid. supra cit.* p. 260.

(*b*) *Carboniferous Sandstones.* The sandstones of this series are the most valuable in Scotland for building materials, and are largely developed on both sides of the valleys of the Clyde and Forth. Their presence in the immediate vicinity of Edinburgh and Glasgow has greatly contributed to the substantial character of the dwelling-houses, as well as of the public buildings, of these cities; a character which strikes the eye of a visitor on arriving from the great brick-formed cities of England.

The geological position of these building stones is far down in the Carboniferous series; a position, in fact, corresponding to the mountain limestone of England;—the formation having completely altered its physical character in its extension into Scotland. As here developed, it consists of light yellow, or white, sandstones and grits, of various degrees of fineness, interstratified with shales, beds of ironstone, and coal, together with several bands of limestone. The sandstones when first extracted from the quarry are often beautifully white, but ere long, after being placed in position, assume a sombre aspect, due to the smoke of thousands of chimneys. The following are some of the principal quarries in the neighbourhood of Edinburgh and Glasgow :—

Quarries of Lower Carboniferous Sandstone.

Binnie, near Uphall, Linlithgowshire. Fine-grained, light brown or grey siliceous sandstone; durable, and suitable for decorative purposes. Used in the New Club House, Princes Street, Edinburgh; the ornamental fountain in front of Holyrood Palace; and numerous private houses in Glasgow and Edinburgh.

Bishop Briggs, near Glasgow. Light brown to white freestone, in thick beds, moderately fine-grained, and yielding large blocks. Stone used in Glasgow for building purposes.

Cat Craig, Carridon. Light grey, fine-grained, siliceous stone, regularly bedded.

Craigleith, near Edinburgh. Light grey, or brown, approaching white, fine-grained freestone, in beds varying from a few inches to twelve feet, interstratified with shales, and showing a vertical depth of about 250 feet. This stone has been largely employed in the public, as well as the private buildings of Edinburgh, including the University, Law Courts, Royal Exchange, 'National Monument,' and numerous churches. It has also been used in London and exported to the Continent. Good specimens resist crushing to the extent of 5000 lbs. to the square inch.

Crawbank, Borrowstounness, Linlithgowshire. Light yellowish brown, fine-grained freestone, yield-

ing blocks of large size. Used in a Roman bridge, A.D. 140, and the old church of Kinneil, 12th century. Other quarries in the neighbourhood.

Dunmore, Stirlingshire. Light grey, fine-grained sandstone of good quality.

Giffneuch, near Glasgow. Pale grey to white, generally fine-grained freestone, of good quality, and adapted for the higher classes of public and private buildings. Used extensively in Glasgow, and in the more ornamental portions of the New University buildings in that city.

Humbie, Linlithgowshire. Pale grey and light brown sandstone, fine-grained, sometimes micaceous, and yielding large blocks. Used in Newliston House, Dundas Castle, additions to the Royal Institution, Edinburgh, the spire of Tron Church; and also in the Royal Exchange, Glasgow.

Paisley. To the north of this town there are numerous quarries of white, or light brown, freestone, sometimes coarse and massive, at other times fine-grained, and apparently well calculated to withstand the action of the atmosphere. They belong to the Lower Carboniferous series.

CHAPTER IV.

SANDSTONES OF IRELAND.

THE sandstones of Ireland, suitable for building purposes, belong to the Old Red Sandstone, the Carboniferous, and the Trias, or New Red Sandstone, systems; and are distributed chiefly in the north and south of that country, the central portions being formed of other materials.

(*a*) *Old Red Sandstone.* The sandstones of this system are distributed chiefly throughout the counties of Cork and Kerry, and consist of greenish, purple, red, and greyish grits, flagstones, and conglomerates; the uppermost member producing fine-grained flags and tiles, which, at Kiltorcan, yield impressions of fern-like plants in a state of remarkable preservation.[1] Amongst the best building stones of the counties of Cork and Kerry are the following:[2]

Mallow. Hard sandstone; brown colour, and yielding flagstones, and blocks suitable for steps, window sills, &c.

Kanturk, and *Macroom.* Hard brown, and liver-coloured sandstones; expensive to work, but durable.

[1] See Memoirs Geol. Survey of Ireland. Maps 147 and 157, p. 14.
[2] Mr. G. Wilkinson, Prac. Geology, p. 172.

Youghal. Sandstone of a reddish grey colour, capable of being dressed.

Ardmore, on the borders of Waterford. Red sandstone, changing on exposure to grey; very durable, as shown by the condition of the Round Tower.

Skibbereen, and Sherkin Island, Baltimore. Greyish sandstone, soft on being cut, but hardening on exposure.

Glandore. Greenish sandstone, or hard grit; used in many of the mansions of the country, as also in ancient buildings, as Ballymoney Castle.

(*b*) *Carboniferous Sandstones and Flags.* The Lower Carboniferous rocks, lying below the limestone, produce either yellowish grits and conglomerates, as in County Longford, or greyish and yellowish flagstones, as in County Mayo. In a higher geological position, we have a series of flaggy sandstones, extensively distributed through portions of the counties Clare,[1] Limerick, Tipperary, Carlow, Kilkenny, and Queen's County,[2] occupying a position immediately under the Coal-measures; while towards the north-west we find, in Leitrim and Fermanagh, massive grits and conglomerate sandstones occupying a similar geological position; and, in all probability,

[1] Mr. F. J. Foot, Expl. Mem. Geol. Survey. Maps 114, 122, and 123, p. 9.

[2] Messrs. J. B. Jukes and G. H. Kinahan. Expl. Mem. Map 137, p. 10.

referable to the Millstone Grit formation of England. Yellowish and reddish sandstones, capable of producing good building stone, are distributed throughout parts of Londonderry, and Tyrone.[1] Near Cookstown, in this county, a fine-grained white freestone, belonging to the Lower Carboniferous series, is quarried and extensively used for finer kinds of architecture in Belfast and neighbourhood. Along the coast of County Antrim, at Ballycastle, large blocks of reddish, yellow, and white freestone might be quarried, and shipped to any port in England, Scotland, or Ireland.[2]

Carlow Flags. These flagstones are largely worked in portions of Carlow and the adjoining counties. They consist of hard dark-blue and grey flagstones, sometimes micaceous, and showing tracks of annelids, and, probably, of crustacea or molluscs. They are imported into Dublin by canal; and amongst other quarries those in the parishes of Shankill and Oldleighlin, of Kilrush and Money Point in Clare, may be specially named.[3] These flags all belong to the Carboniferous formation. Millstones and grindstones were formerly obtained from the Millstone Grit for-

[1] Portlock's Geol. of Londonderry, Tyrone, &c.

[2] For details of the building sandstones of different parts of Ireland, the reader is referred to the useful work of Mr. G. Wilkinson, already quoted.

[3] Explanation of sheets 147 and 157 of the Maps of the Geol. Survey, by Messrs. Jukes and Kinahan.

mation of Cuilceagh, a high ridge on the borders of Leitrim and Fermanagh; and from Drumdowney in Kilkenny.[1]

(*c*) *New Red Sandstone.* (Bunter.) This formation is extensively distributed along the southern and western borders of County Antrim, occupying the rich and fertile valley of the Laggan, and stretching for some distance along both shores of Belfast Lough. In this district, it consists for the most part of soft red marly sandstone unfit for buildings, except those of a temporary character, and is more adapted for the production of moulding sand for foundry purposes. There are, however, a few places near Holywood and Newtown Ards where this red sandstone, after having been quarried, hardens on exposure; but its durability may well be questioned. All these beds belong to the Bunter sandstone—the lowest member of the Trias.[2]

(*d*) *Lower Keuper Sandstone.* At Scrabo Hill, however, which rises to a considerable elevation above the surrounding country from the northern shores of Strangford Lough, sandstones belonging to the upper division of the Trias—the remnants of a once more widely extended formation—are to be found; very similar in appearance, and identical in geological position, to the freestones of Bidston Hill,

[1] Sir R. Kane, Industrial Resources, p. 233.

[2] Expl. Mem. Geol. Survey, Ireland, Map 36, p. 8.

New Brighton, and Manley in Cheshire.[1] These sandstones are harder and more durable than those of the underlying Bunter division; and are also of an agreeable colour, varying from light reddish-brown, to grey, yellow, and white; they are easily worked, and suited for ornamental sculpturing; these quarries also yield flagstones.

The sandstone is overlaid by a great sheet of basalt and dolerite, and numerous horizontal and vertical dykes of similar igneous rocks perforate the beds, so as not only to interfere with the excavations, but also seriously to injure large masses of the stone itself. Notwithstanding this natural drawback, I know of no sandstone in the North of Ireland so well fitted for architectural purposes of an ornamental character; and for such purposes it is largely used in Belfast, Newtown Ards, and the adjoining country. The crushing weight of this stone has been ascertained by Mr. Wilkinson to vary from 2240 lbs. up to 10,570 lbs. to the cubic inch. The average being about 4000 lbs.[2]

[1] Expl. Mem.. Geol. Survey, Ireland. Maps 37, 38, 39, p. 13.

[2] Prac. Geol. &c. Table of Experiments.

CHAPTER V.

CONTINENTAL SANDSTONES.

France. The principal sources of sandstones fit for building in France are the Devonian, Triassic (*grès bigarré*), the Jurassic, containing the *grès de Luxembourg*, and the Tertiary series of the Paris basin, which yields the *grès de Fontainebleau*. In the Vosges there are the sandstones of the Permian and Trias in a position of almost relative conformity.[1]

Quarries. The most important quarries are those of Villéry, and those on the borders of the canal of Languedoc, by which large blocks are carried to Toulouse and other towns. The stone belongs to the class known as *psammite*, formed of siliceous grains in an argillaceous cement, often with flakes of mica. The town of Carcassonne is entirely built of sandstone from the quarries of Villéry.[2]

The sandstone of Fontainebleau, often called *grès blanc*, or *grès commun*, is chiefly found at the town of that name, at Longjumeau and Pontoise. The quarries of Busagni, near Pontoise, furnish a stone in

[1] M. A. D'Orbigny, 'Cours élémentaire, &c.' ii. 392.

[2] Chateau, i. 184.

much request for hydraulic structures; for although friable in the quarry, it becomes exceedingly hard under water.[1]

Luxembourg. The sandstone of this name (*grès de Luxembourg*) is referable to the lower portion of the Jurassic series. On a rock of this sandstone the strong fortress of Luxembourg is built. The red sandstone at Hommartin (Meurthe) has furnished most of the stone for the churches and buildings of Lorraine, such as those of Saint Wandel and Sarrebrück, remarkable for their rich brown colour.

Germany. The New Red Sandstone (Bunter Sandstein) is much employed for building in some parts of Germany. At Heidelberg it rises into the lofty ridge of the Kaiserstuhl, and from the quarries of the vicinity the grand old castle, together with many of the buildings of the town, have been constructed. The stone has a reddish tint, which affords a pleasing contrast to the green of the forests which rise behind the buildings along the banks of the Neckar.

The *grès de Wurtemberg,* belonging to the Bunter Sandstein formation, is quarried in the Black Forest. It is of excellent quality, generally fine-grained, and the grains being cemented by silica it is exceedingly durable. Of this stone the beautiful gothic Cathedral of Cologne is chiefly constructed.

[1] Chateau, i. 185.

The specific gravity varies from 2.22 to 2.36.[1] The Keuper formation also yields a useful sandstone, varying from red to white, sometimes coarse-grained, and refractory. It is quarried at Tübingen, Mertingen, and Stuttgart; the finest quality is produced at Schlaydorf, and Holsteinbruch.

The Bunter Sandstein of the neighbourhood of Trèves furnishes excellent material for building purposes; the quarries are situated at Beilinger, Lorig, Udelfang, Wasserliesch, and Hiltengend.

Near Aix-la-Chapelle there is a white sandstone of great beauty, being composed of grains of pure quartz. It is easily worked, and suitable for sculpture, while it can be obtained in blocks of large size; the quarries are situated at Herzogenrath. The sandstone of Phalsburg is of a similar character.[2]

Switzerland. The Tertiary formation known as the 'Molasse,' is largely developed in the great valley of Switzerland, and produces a greenish sandstone, largely employed for building purposes at Geneva, Berne, and Lausanne. The quarries from which the building stone of Geneva is supplied, are situated on both banks of the lake; those for Lausanne and Berne are close to these cities respectively.

Italy. Sandstone is not largely employed as a

[1] M. Delesse, quoting from M. Wagner, Matériaux de Constr. de l'Expos. Univ. de 1855.

[2] Chateau, i. 190.

building stone in this country. The chief sources being in Tuscany, the capital of which province is largely constructed with a dark greenish sandstone, quarried along the banks of the river Arno some miles below Florence itself. This stone, which when fine-grained is called 'mascigno,' when coarse, 'cicerchia or cicerchina,' is variable in quality and composition, passing from a flag and paving stone into a massive building stone, and from a fine-grained sandstone into a conglomerate. It is used for paving and building both at Florence and Pisa; and according to the observations of Sir R. Murchison belongs to two geological periods, namely:—the Cretaceous on the one hand, and the Eocene Tertiary stage on the other, the two masses being separated by beds of nummulite limestone. The upper beds attain to a great thickness in the hills south of Santa Martino.[1] Large quarries of macigno sandstone, similar to that near Florence, are opened near Agosta along the valley of the Teverone amongst the Sabine Hills.

[1] 'On the Geol. of the Alps, Apennines,' &c. Journ. Geol. Soc. Lond. v. 277.

CHAPTER VI.

SANDSTONES OF INDIA.

SEVERAL formations of Northern India produce excellent sandstone for building purposes, which have been largely used. Amongst these, the stone derived from the 'Vindhyan' series is the most valuable. It is very widely distributed in the Nerbudda Valley, and neighbouring districts, and consists of several thick masses of sandstone of a light colour, uniform texture, and, while durable, it is not difficult to work.

Of this stone many of the chief cities and buildings in the north-west provinces, the Punjab, and the Ganges Valley are partially constructed. Allahabad, Benares, Agra, and Delhi have all drawn their supplies from thence; and of this material have been erected the proudest monuments of the Mogul dynasty. It was used by Akbar for his palace of Futtipursikri, and the forts of Agra and Allahabad; by Shah Jehan for portions of the Taj at Agra, as well as for the Jumna Musjid at Delhi, and by Aurungzebe for the palace at Benares. More recently, some of the largest engineering works, including the piers of the

East Indian railway bridges over the Jumna at Allahabad and Delhi, have been constructed of this material.[1]

Excellent building sandstone is also obtained from the Lower Damuda group, and Ranigari beds in Bengal.[2]

[1] Mr. F. R. Mallet, F.G.S., Mem. Geol. Survey of India, vol. vii. part I.

[2] Mr. W. F. Blandford, F.G.S., Mem. Geol. Survey of India, vol. iii.

CHAPTER VII.

SANDSTONES OF NORTH AMERICA.

Canada. Sandstones suitable for building purposes, are to be found in the Huronian series, as yet little in demand, and in the Potsdam formation. This latter, in its extension eastward of Kingston, furnishes a white freestone, durable and fireproof, but rather hard.

At Lyn, near Brockville, massive beds of superior quality have been worked for material with which to construct the new Parliament Buildings of Ottawa. Other localities in which the Potsdam formation yields serviceable freestones are Beauharnois, Hemmingford, Veaudreuil, Nepean, Ramsay, and Pakenham.

The Quebec group affords building stone used in the city of that name, as also does the Chazy formation. One of the most valuable is the 'grey band,' extending from Queenstown to Collingwood; it varies from 10 to 20 feet, and furnishes excellent building stone, which is largely used in many towns of west Canada. Of this stone the University College at Toronto, and many of the buildings at Hamilton, are constructed.

The Oriskany sandstone of the Devonian age furnishes millstones, besides white freestones for building, as do also the Gaspé and Hudson River group of the Upper Devonian series.[1]

United States. Only a few of the most valuable building sandstones can here be noticed. New Jersey and Connecticut contain a dark red sandstone, which is serviceable when fine-grained and compact; of this stone Trinity Church, New York, is built.[2] At Chatham, on the Connecticut, and along the river are numerous quarries which supply the towns on the coast. A variety in North Haven, and at the east end of Mount Carmel, has been commenced for ornamental architecture. The stone of Longmeadow and Wilbraham in Massachusetts, that at the mouth of Seneca Creek, Maryland, and the white and coloured freestones of Sugarloaf Mountain in the same county are largely used. The sandstone of the Capitol at Washington is from the Potomac, but of inferior quality.

[1] The above details are condensed from Logan's 'Geology of Canada,' 1863.

[2] Dana, Man. of Min. p. 361.

PART XII.

RARER BUILDING STONES.

CHAPTER I.

TRAVERTINE.

TRAVERTINE, anciently called *lapis Tiburtinus*, is the principal building stone of ancient and modern Rome. According to the views of Lyell, Bischof, and other observers, this rock has been formed by the precipitation of calcareous matter from water charged with carbonic acid gas; and the enormous masses accumulated at Tivoli were deposited in an extensive lake, which existed at the close of the period of volcanic activity, during which the lavas and tuffs of the Roman territory were formed.[1] Its manner of formation may still be witnessed at the Lago di Zolfo in the Campagna, and at the cataract of the Anio at Tivoli.

The travertine used in Rome is chiefly derived from quarries at Tivoli. It is a straw-coloured,

[1] Lyell, Principles of Geol. 10th edit. i. 405. Also Bischof, Chemical Geology, i. 155.

tufaceous limestone, cellular and porous, and exhibiting in section lines of wavy lamination. When first extracted from the quarry it is sufficiently soft to be cut by the saw, but hardens on exposure, and under an Italian sky seems to be almost indestructible. It is laid open in sections along the banks of the great chasm, into which the waters of the Anio precipitate themselves, and shows horizontal beds of alternating tufa and travertine, attaining a thickness of nearly 500 feet. From the days of the Emperor Augustus, who selected it, and white marble from Carrara, for the numerous buildings and restorations undertaken under his auspices, this rock has been largely employed in Roman buildings; and is still in use.

Architectural Illustrations. First, amongst the buildings of ancient Rome constructed of travertine, must be named the Amphitheatrum Flavium, or Colosseum, the largest theatre in the world, capable of seating 87,000 spectators; founded by Vespasian in the middle of the first century. The exterior of this truly colossal structure was entirely built of travertine, and of an elliptical form, consisting of four tiers of arches, the three lowest being embellished with half columns of Doric, Ionic, and Corinthian orders. The interior was almost entirely formed of brickwork. During the 15th and 16th centuries the Colosseum was regarded, and treated, as a sort of quarry, from which materials were obtained for the

construction of more recent edifices. Here Paul II procured materials for the Palazzo di S. Marco in Venice; Cardinal Riario for the Cancelleria; and Paul III for the Palazzo Farnese.[1] Subsequent popes, however, have come to the rescue of the structure, and averted the fate which their predecessors had intended for it, by building massive buttresses at either end of the portion of the uppermost story which still remains.[2]

Of modern structures in Rome built of travertine are the external walls of nearly all the churches, including St. Peter's, together with the grand colonnades of Bernini, which partially enclose the Piazza. Of similar stone are built the palaces and public, as well as private, buildings of Rome, including the Museum and Church of the Lateran, the Castle of St. Angelo, the Quirinal, and portions of the walls of the city, in which however brick was most generally employed.

The building stone of Naples is a species of calcareous tuff, or travertine, from the vicinity, formed, in all probability, by the deposition of volcanic materials over the former bed of the sea. It is scarcely equal in quality to that of Rome, being rather softer,

[1] Bædiker, Central Italy, p. 177.

[2] That travertine was used from very early times in ancient Rome is shown by the Arch of the Cloaca Maxima, which is partly formed of it.

and of a yellowish-brown colour. Of this stone the colonnade of the Piazza del Plebiscite is formed. For the more exposed and stronger kinds of masonry grey lava from the base of Vesuvius is used in Naples.

Amongst the most ancient cities of Southern Italy travertine has been in use. Thus we find it occasionally amongst the ruins of Pompeii, where it was used for corner stones and pillars to houses built of concrete. The walls and columns of Paestum, constructed of a similar material, are still in a remarkable state of preservation.

From the manner in which the buildings and monuments of Italy, formed of calcareous materials, have retained to a wonderful degree the sharpness of their original sculpturing, unless disfigured by the hand of man, it is clear that a dry and smokeless atmosphere is the essential element of durability. In this respect, therefore, the humid sky and gaseous air of British towns must always place the buildings of this country at a comparative disadvantage as regards durability.

CHAPTER II.

VOLCANIC TUFF, OR PEPERINO.

THIS material, formed of lapilli and ashes ejected from modern volcanoes, and bound together by various cements, such as carbonate of lime and silica, has been occasionally employed in France and Italy as a building material for structures of secondary importance. It is very light, of a specific gravity of 1.22–1.95, and consequently adapted for vaults or small arches.

It is found abundantly in the volcanic district of Central France, and in the Haute-Loire has been used in the construction of churches and dwelling-houses. The Peperino of the Campagna of Rome and Naples is a volcanic tuff, which has been used in some of the less important buildings of thòse cities; and it has also been used in the houses of Herculaneum and Pompeii.

Varieties of tuff from Monte Verdi have been quarried and used at Rome to some extent.[1]

LATERITE OF INDIA. This is a peculiar formation,

[1] Specimens presented by Mr. W. W. Smyth, F.R.S., are deposited in the Museum of Practical Geology.

occupying large portions of the plains of Madras and Bengal. It appears to be an ancient alluvial formation of gravel and conglomerate, cemented more or less by a ferruginous paste; and in the Madras Presidency Mr. Bruce Foot, of the Geological Survey, found it to contain works of human art, in the form of flint implements. In Midnapore and Orissa, as well as at Tanjore and Trichinopoly, it has been employed for building purposes from early times; having been used in the construction of temples and other ancient structures as well as dwellings. When first taken from its bed it is very soft, but hardens on exposure, and is very durable.[1]

[1] Mr. Blandford, Mem. Geol. Survey of India, vols. i. and iv.

PART XIII.

ROOFING SLATE.

CHAPTER I.

CLAY-SLATE.

Gemeiner Thonschiefer (*Germ.*); schiste argileux commun (*Fr.*).

CLAY-SLATE is a sedimentary argillaceous rock, generally compact and fine-grained, of colours varying from grey to purple, green, and even black, and splitting along planes of cleavage which only accidentally coincide with those of bedding. These slates are chiefly used for roofing houses and public buildings, and are valuable in proportion to their compactness and durability, the smoothness of the surface which they present, their uniformity of colour, and incapacity for absorbing water.

Cleavage. The phenomena of cleavage have engaged the attention of physical geologists, both in our own country and abroad, and especial light has been shed on its origin by the observations of Mr. D. Sharpe[1] and Mr. Sorby,[2] who, having subjected cleaved

[1] Journ. Geol. Soc. Lond. iii. 74, and v. 3.
[2] Edinb. New Phil. Journ. iv. 137 (1853).

rocks to microscopical examination, found that the component particles had undergone elongation and a certain degree of re-arrangement, which is obvious to every one who has examined cleaved fossiliferous strata, and which can only be attributed to mechanical pressure.

Mr. Charles Darwin has observed, with reference to the relations of cleavage to foliation, that in the Andes the dip and strike planes coincide, and has concluded that the latter may be the extreme result of the process of which cleavage is the first effect.[1]

Professor Ramsay, after having observed these phenomena in North Wales and Anglesea, showed that in this latter country cleavage had followed metamorphic action, resulting in foliation, and that there is, therefore, no necessary connection between them; 'but that if rocks be uncleaved when metamorphism occurs, the foliation-planes will be apt to coincide with those of bedding; and that if intense cleavage has preceded, we may expect that the planes of foliation will lie in the planes of cleavage.'[2]

The mechanical theory of cleavage, as illustrated

[1] Geology of South America. An excellent summary of the views of Sedgwick, Herschel, Phillips, &c. will be found in Lyell's Elements of Geology.

[2] Journ. Geol. Soc. Lond. ix. 172. Mr. G. H. Kinahan, of the Geol. Survey of Ireland, from an examination of the foliated rocks in Galway, seems to have arrived at similar conclusions. Explanatory Memoir on sheets 105, 114 (Galway).

by Professor Phillips, Mr. D. Sharpe, and Mr. Sorby, is that which is now generally adopted by geologists; and is one which seems to explain most readily the various appearances connected with the presence of cleavage itself. According to this view, the terrestial forces acting in a lateral direction have not only contorted the beds, but by changing the dimensions of the rocks have so re-arranged the laminæ or particles, as to cause a very great majority to lie in a plane perpendicular to the direction of the forces themselves.

Geological Formations. As far as the British Isles are concerned, cleaved slates are confined to the Palæozoic formations, from the Cambrian down to the Carboniferous inclusive. On the Continent, however, it is otherwise; and both in the Pyrenees, the Alps and Apennines strata belonging to the Mesozoic and even Tertiary periods present the phenomenon of cleavage, which is altogether independent of geological age. It seems probable, however, that unless a great resistance—due to the weight of large masses of strata—has been offered to the forces acting in a lateral direction, the result will be not cleavage but simply crumpling or contortion of the strata; and from this it follows, that the older rocks are generally those in which cleavage has been developed, and that we may suppose that enormous masses of material have been removed from off the surfaces of those districts

in which cleaved rocks are to be found.[1] We may therefore infer, that the Lower Silurian rocks of North Wales, the Devonian and Carboniferous slates of Devon and Cornwall, and those of the Lower Carboniferous age of the South of Ireland have been subjected to denudation on a large scale.

Results of Cleavage on the structure of the Rocks. The direction of the planes of cleavage is independent of that of the planes of bedding; and we, therefore, have these planes intersecting each other at various angles, or accidentally coinciding. In general, however, the tendency of the rock to split along the planes of cleavage predominates, so that a slab of slate is equally strong throughout, though crossing several divisional layers of original stratification. This is the case in all good roofing slates, in which we may frequently observe the layers of bedding crossing the surface in a series of parallel bands indicated by faint shades of colour, or slight differences of texture. At the same time, it has been frequently observed, that amongst strata composed of various materials, such as sandstone and slate in alternate bands, the cleavage planes take different directions in the different beds, depending on the amount of resistance the materials have been able to offer to the lateral forces.

[1] Professor Ramsay, Descrip. Catalogue of Rock Specimens M. P. G. p. 122 (1858).

Uses of Slate. It is scarcely necessary to attempt an enumeration o the uses to which slate, such as that of North Wales, is applicable. The superiority both in durability, and especially in regard to lightness (or less weight), of Welsh slate for roofing purposes, has caused it to supersede, since the introduction of canals and railways, those bedded fissile *tilestones* (sometimes erroneously called 'slates') which were in use in many parts of the country, and which were derived from the Upper Silurian, the Carboniferous, and the Oolitic formations.[1] But while in some respects this has been an advantage, it has been otherwise as regards architectural taste; for while the heavy tilestones were employed, high pitched roofs were a necessary consequence, but the introduction of the Welsh slates has been generally accompanied by the construction of flattened roofs; an alteration certainly not in the direction of architectural beauty.

Besides its use as a roofing material, slate is very properly applied to the construction of cisterns for holding water, thus doing away with the objectionable use of lead for such purposes. It is also used for ornamental structures, and as a substitute for marble; but although it is capable of receiving a fair polish,

[1] Viz., the tilestones of the Upper Ludlow, the thin flags, or tiles, of the Millstone or Yoredale series, and the Stonesfield and Collyweston slates of Gloucestershire, Oxfordshire, &c.

its density and absence of crystalline structure are obvious, and it is very inferior in beauty to true marble, which is properly a crystalline carbonate of lime; in fine, the use of slate as an imitation marble is very much to be deprecated, as long as we have abundance of genuine marbles at our command.

CHAPTER II.

SLATES OF GREAT BRITAIN.

SLATE is one of the most dense of stratified sedimentary rocks, one cubic foot weighing from 170 to 180 lbs. per cubic foot. Mr. Wilkinson found that one cubic inch of Killaloe slate required in one case as much as 30,730 lbs. in order to crush it; but the average crushing weight was considerably less, say about 20,000 lbs.[1] The transverse strength of Welsh slate is greater than that of any other mineral product of the stone-kind; and for such qualities as strength, space, and cleanliness, no other material is superior to slate.[2]

The following analysis of an average sample of Welsh roofing slate, serves to show, that as compared with the composition of granite, it contains less silica, and, on the other hand, more alumina.

Analysis of Welsh Roofing Slate. 100 parts.

	Per centage.	Oxygen.
Silica	60.50	32.27
Alumina	19.70	9.19
Iron (protoxide)	7.83	1.74
Lime	1.12	0.32
Magnesia	2.20	0.88
Potash	3.18	0.54
Soda	2.20	0.57
Water	3.30	2.71
	100.03	48.22

[1] Practical Geology of Ireland. Table of Experiments.

[2] Gwilt, Encyc. Arch. p. 522.

U 2

The finest roofing slates in Britain, perhaps in the world, are obtained from North Wales, and are derived from three formations:—

First: The Cambrian, producing generally green and purple slates.

Second: The Llandeilo beds of the Lower Silurian, producing generally black, or dark, slates.

Third: The Caradoc, or Bala beds of the same period, producing generally pale-grey slates.

(*a*) *Cambrian Slates.* These are quarried in immense excavations at Llanberris Pass and vicinity, following the northern outcrop of the strata from the flanks of the Snowden range in a N.N.E. direction. The Penrhyn quarries are worked in successive terraces in the form of an amphitheatre; the rock is detached in immense masses by blasting, and is then sorted and cut to the various sizes suitable for the market. From the quarries in this neighbourhood the demands of London and the northern towns are supplied, while large quantities are exported to Scotland, Ireland, and even America.[1]

(*b*) *Lower Silurian Slates.* These are quarried near Ffestiniog, and shipped at Portmadoc; also at Machynlleth, Aberdovey, Barry Island, Dolwyddelan, and at Llangollen. These last named

[1] See account of these slate rocks by Professor Sedgwick, Journ. Geol. Soc. Lond. iii. 540, and iv. 213. Also Prof. Ramsay, 'On the Geol. of North Wales,' Mem. of Geol. Survey, p. 155.

quarries are remarkable for the size of the slates they are capable of producing; a slab from the quarry of the Llangollen Slate Company having been sent to the International Exhibition of 1862 which was 20 feet long, 10 feet wide, and weighed 4½ tons. The Welsh Slate Company, whose quarries are at Ffestiniog, sent several slabs, averaging 14 feet by 7 or 8 feet. All the slate from this neighbourhood possesses the remarkable quality of splitting with great facility, and with wonderful accuracy of surface, into thin laminæ, or sheets. Some of these thinly divided sheets are obtained 5 to 10 feet long, and from 6 to 12 inches wide, and not more than the 16th of an inch in thickness; they are so elastic that they bend like a veneer of wood.[1]

Amongst the numerous slate quarries of North Wales, worthy of especial notice may be mentioned the 'Dorothea West,' in Carnarvonshire, supplying green, blue, and red slates; those of the 'Llanfair Green and Blue Slate Company,' and the 'Royal Slate Company,' near Bangor.

The following is a list of the Slate Quarries of Wales in the year 1860[2]:—

[1] Mr. R. Hunt, Handbook to Exhibition of 1862.

[2] From Mr. R. Hunt's Mineral Statistics for 1858, part ii. (1860).

Name of Quarry.	Nearest Railway Station or Shipping Port.	Name of Stone.	Buildings in which used, and Purposes to which applied, and Remarks.
RADNORSHIRE.			
Abbey-cwm-hir	Rhayader	Slate.	
CAERMARTHENSHIRE AND PEMBROKESHIRE.			
Pontarllechan........	Llangodog	Slate	Building stone.
MONTGOMERYSHIRE.			
Gaewern	Machynlleth	Blue slate ..	Roofing slates.
Llangynog	Llangynog	Slate	„
Tuno or Braichgoch ..	Machynlleth	Blue slate ..	„
Tyn-y-berth	„	„ ..	„
MERIONETHSHIRE.			
Braich Dhu	Maen-Twrog	Slate and slab	Roofing slate and large slabs.
Braich Goch	Tal-y-llyn	Slate	Roofing slates.
Cefn Cam	Barmouth River..	„	Greenish, very durable slate.
Craig Dhu, Ffestiniog	Portmadoc	„	Roofing slates.
Cwrnorthin..........	„	Slate and slab	Roofing slates and slabs.
Diffwys	„	„ „	„ „
Ffestiniog	„	Blue slate ..	Roofing slate, slabs, &c.
Four more quarries of the same name	„	„ „ ..	„ „
Garthenghared	Dolgelly	Slate	Roofing slates.
Hollands............	Portmadoc	Slate and slab	Roofing slates and slabs.
Llechwedd	„	„ „	„ „
Maenyfferam	„	„ „	„ „
Rhiwbach	„	„ „	„ „
Rhiwbryfdin	„	„ „	„ „
Rhosydd	„	„ „	„ „
Tyn-y-Coed..........	Barmouth	Blue slate ..	Roofing slates.
Votty	Portmadoc	Slate and slab	Roofing slates and slabs.
DENBIGHSHIRE.			
Cambrian	Llangollen	Slate	Roofing slate.
Fron	Llandurog	„	Roofing slates and slabs.
Llangollen	Llangollen	„	„ „

Name of Quarry.	Nearest Railway Station or Shipping Port.	Name of Stone.	Buildings in which used, and Purposes to which applied, and Remarks.
		CARNARVONSHIRE.	
Bangor	Bangor	Slate	Roofing slates and slabs.
Braichrhydd	Carnarvon	"	" "
Bwlch-y-Gwes	"	"	" "
Cofn-du	"	"	" "
Cilgwyn	"	"	
Cloddfar Lôn	"	"	
Cwm Eigia	Tal-y-Cafn	"	Roofing slate.
Dinorwic............	Port Dinorwic ..	"	Roofing slate, slabs, &c.
Dorothea............	Carnarvon	"	" "
Glynrhouwy	"	"	Roofing slate.
"	"	"	"
Gorseddan	Portmadoc	"	
Hafodlas...	Carnarvon	"	
Moel Tryfan	"	"	
Pantdreiniog		"	
Penmachno	Trefriw & Conway	"	Roofing slates and slabs.
Penrhyn	Bangor	Slate and slab	" "
Penorsedd	Carnarvon	Slate	
Talysarn............	"	"	" "
Tymawr	"	"	
Tyn-y-worglodd......	"	"	" "
Vron	"	"	

(*c*) *Cornwall.* The Delabole quarries, from strata belonging to the Devonian formation, have been worked for a long period. The colour of the slates is grey or blue, and they are shipped from Tintagel, and Boscastle. The Wellington College at Sandhurst is roofed with Delabole slate.[1] The Tavistock slates from Devonshire were once in much demand;

[1] De la Beche, Geological Rep. of Devon and Cornwall, p. 502 (1839).

there are also quarries at Ingsdon, near Bickington; East Down, between Ogwell and Ashburton; at Bow, near Staverton; at Tigley and Moor, near Rattery; and at Cann Quarry, near Boringdon Park.

(*d*) *Lake District.* 'Westmoreland Slate,' from the Upper Silurian rocks of the neighbourhood of Kendal, of a pale blue and green colour, is much esteemed; similar slates are also quarried at Ulverstone in North Lancashire.[1] From the Lower Silurian rocks of Skiddaw, sea-green slates are extracted, and shipped from Maryport.

(*e*) *Scotland.* Owing to the metamorphic condition of the Lower Silurian rocks of the Scottish Highlands, they are rarely capable of producing good slates for roofing purposes. The most important quarries are those of Ballachulish in Inverness-shire, and from which from five to seven millions of slates are annually extracted,[2] the weight of which may be estimated at 10,000 tons. The refuse, amounting to five or six times this quantity, is thrown directly into the sea.[3]

Slates are also worked at Benledi and Birnam, in Perthshire. The latter quarries yielding about 300,000 roofing slates yearly; also at Craiglea and Drumahern, near Perth; at Dalbeattie, near Dunkeld; at Glenalmond and Laurick, near Crieff; and

[1] Gwilt, Encyc. Arch. p. 522. [2] *Ibid.* [3] *Ibid.*

at Tullybeagles near Tynedrum. In Forfarshire, slates are also worked at Hoyston and Turin, near Forfar; and in Aberdeenshire at Fondland, near Aboyne; and at Gartley and Troup Head, near Inverary.[1]

(*f*). *Ireland.* The principal quarries are those of Killaloe, Co. Tipperary; Valencia, Co. Kerry; Benduff, near Glandore Harbour, Co. Cork; those near Carrick-on-Suir; also Ashford Bridge, and Rathdrum, Co. Wicklow.

The Killaloe slate quarries are situated at Corbally, and are worked in strata belonging to the Lower Silurian rocks.[2] These quarries lay open a vertical section of over 350 feet, and produce slates from ten feet square downwards, of a dull bluish-grey colour, and of good quality, though somewhat rough.

The slates of Valencia, from the Devonian series, somewhat resemble those of Killaloe, but have a greener tinge. Mr. Wilkinson states that they are also inferior in quality to those of Killaloe, being thicker, and splitting with a less even surface; but from this locality flagstones for cisterns, baths, &c., are largely exported to England. There are also

[1] Mr. R. Hunt, Mineral Statistics, part ii. 1858.

[2] See Map of the Geol. Survey, sheet 134, with Explanation, by Messrs. Kinahan and Wynne, Mem. Geol. Survey, p. 25 (1861). Also Kane's Industrial Resources, p. 230.

quarries in the Lower Carboniferous slate of the south-east of Co. Cork at Clonakilty, and at the Old Head of Kinsale, yielding roofing slate of a good quality, exceedingly light and durable.[1] The slates of Ashford Bridge resemble those of Bangor in Wales,[2] while those of the Victoria Slate Company, near Carrick-on-Suir, are not unlike those of Keswick or Penrhyn, being smooth, of a light green colour, and of excellent quality.

It is not improbable that the West and South of Ireland may be found capable of yielding far larger quantities of this valuable commodity than hitherto; but which, for want of capital and perseverance, have not been rendered available. Amongst the Lower Silurian rocks north of Hillary harbour, and along the valleys of the Erriff and Doo Lough, in Co. Mayo, are certain beds, which, if opened up at sufficient depth, might be found to produce excellent pale-grey or bluish roofing slate; and to this district I venture to direct the attention of capitalists.

[1] Kane's Industrial Resources, p. 231.

[2] Mr. Wilkinson has experimented on varieties of micaceous, talcose, and chloritic schists from Donegal, which cannot, however, properly be included amongst ordinary roofing slates.

CHAPTER III.

SLATE ROCKS OF THE CONTINENT.

Schistes Ardoisières (*Fr.*).

France. Roofing slate is obtained at several localities in France; but the two principal centres of quarrying are Angers, Poligny, &c., in the Department of Maine-et-Loire, and the Ardennes on the north-eastern borders of the country. The quarries of Angers have been worked from very ancient times; the slate is of a blue or dark-blue colour, and is extracted both in open work and in subterranean galleries; it is also of good quality. It has afforded fossils which have enabled MM. E. de Beaumont and Dufrenoy to refer its age to that of the Llandeilo formation (Lower Silurian) of Britain.[1]

The schistose rocks of the Ardennes, on the other hand, have been determined by Professor Sedgwick and Sir R. Murchison to belong to the Devonian system.[2] They are very largely quarried in some places, particularly at Rimogne, Fumay, and Deville. Slates are also obtained in the departments of La Sarthe, Mayenne, Finisterre, Calvados, and Les Landes.[3]

Belgium, &c. The slates of Luxembourg belong to

[1] Murchison's Siluria, 3rd edit. ch. xv.

[2] Trans. Geol. Soc. Lond. vol. vi. [3] Chateau, ii. 268.

the same geological series as those of the Ardennes. They are extracted in large quantities, and used both in Belgium and France, the chief localities being those of Geripont, Herbeumont, Bertrix near Neufchâteux. According to M. Chateau, the slates of Luxembourg are inferior in quality to those of the Ardennes.[1]

Germany. Roofing slates are obtained from the Devonian and other formations of Nassau, Würtemberg, and Westphalia.

Austria and South Germany. Slates are obtained from the older Palæozoic formations of Moravia and Silesia extending throughout an extensive tract of country, the chief seat of the industry being Waltersdorf, near Olmütz. The slates vary from grey to blue and black, and are receptive of a good polish, on which account they are not only employed for flagging and roofing purposes, but also for tables, boxes, and cisterns.

Italy. The Liassic strata of some portions of the Apennines have undergone metamorphism to such an extent, especially in that part known as the 'Apuan Alps,' that they have assumed the outward character of Palæozoic rocks. In this manner we find roofing slates extensively quarried at Cardosa, in the valley of the Vezza, above Seravezza in Tuscany, and at Lavagna and Chiavari, not far from Genoa, the latter being most esteemed. In the capital of

[1] Chateau, ii. 279.

Tuscany, however, red artificial tiles are almost exclusively in use for roofing purposes; except in the case of the beauteous cathedral, the roof of which is formed of thin slabs of marble.

Savoy possesses beds of roofing slate, but of little importance, and difficult to work and transport. The chief quarries are those of Cevins, in Haut-Savoie, and those of Bellecombe in Tarentaise. These slates are probably referable to the Liasso-Jurassic series.

Sweden and Norway. Slate quarrying has not until recently been extensively carried on; and it is only since 1850 that the use of slates has become pretty general. In 1855, there existed only four quarries in Sweden:[1]

1. That of Glava, in Vermland, which is the oldest;
2. That of Gyfkihlen, near Gothemburg;
3. That of Halla, in Vermland and Dahlsland;
4. That of Kjellsvik, in Dahlsland.

The three first produce slates generally thick; that of Kjellsvik, on the other hand, is sufficiently important, giving, in 1855, employment to 400 workmen. The slates from this quarry (situated near Lake Wener, or Wenern) are fine-grained, even, and of good quality, comparable with those of Wales.[2]

[1] Chateau, ii. 280.

[2] *Ibid.* M. Delesse has given a list of the sizes, forms, and prices of the slates from this quarry in 1855 (Matérieux de Construction de l'Exposition Universelle de 1855).

CHAPTER IV.

SLATE ROCKS OF THE AMERICAN CONTINENT.

Slate Rocks of Canada. Amongst the rocks of the Quebec group (Lower Silurian), clay-slate has been wrought successfully. In this series are the slates of the Walton Quarry, on the twenty-second lot of the sixth range of Melbourne, which offer facilities for extensive working. The band is one-third of a mile in breadth, and produces roofing slate of a bluish-purple colour, fine-grained, and splitting into thin plates with smooth surfaces. The following is a list of prices per square, as delivered at the Richmond Railway Station,[1] one mile and a half from the quarry :—

Dimensions and prices of Melbourne Slates.

Inches.	Number.	Price.
24 x 14	98	4.25
22 x 12	126	4.25
20 x 10	169	3.25
18 x 10	192	4.00
16 x 9	246	3.75
14 x 8	327	3.00
12 x 8	400	2.50
16 x 6	533	2.00

The slate band of Melbourne is continued into Cleveland, but the quarry opened on it in 1854 was

[1] Logan, Geol. of Canada, p. 830.

afterwards abandoned. Roofing slate has also been found at Kingsey and Frampton, in the former place associated with dolomite.

On the second lot of the fifth range of Orford there are slates of a dark-bluish colour, similar to those of Melbourne, except that they are not so smooth in their cleavage; and again on the fifth range of Brompton and at Westbury on the St. Francis river. These are referable to the Upper Silurian stage. Other beds are associated with flagstones in Tring, and on the Rivière du Loup.[1]

United States. Roofing slates are obtained at Barnard, Piscataquies, Kennebec, and Bingham, in the state of Maine; at Boylston, Lancaster, Harvard, Shirley, and Peperell, in Massachusetts; at Guilford, Brattleborough, Fairhaven, and Dummerston, in Vermont; at Hoosie, New York; on Bush Creek, and near Unionville, in Maryland; and at the Cove of Wichatta, in Arkansas.[2]

[1] Logan, Geol. of Canada, p. 831.
[2] Dana, Man. of Mineral. p. 358.

PART XIV.

CONCLUDING OBSERVATIONS.

CHAPTER I.

PHYSICAL AND CHEMICAL CHARACTER OF BUILDING STONES.

In the important matter of selecting a stone for a building intended to be of a permanent character, special attention should be paid to the climate of the locality in which the building is to be erected. If the district be one in which there is a heavy annual rainfall, certain stones would be unsuitable; and if the rain, or the atmosphere, is impregnated with acids, still greater care is necessary in the selection. On the other hand, in dry or rainless climates, such as those of Egypt and part of Syria, stone of almost any kind will last unimpaired for indefinite periods. Of this the most notable illustration is the Pyramid of Cheops, upwards of 4000 years old, which is built of Nummulite limestone.

Before entering further on this subject, it may be advisable to define those physical and chemical characters on which the durability of building stones so much depends.

Physical Characters. The physical characters are those of density, hardness, structure, fracture, and colour. These characters generally suffice for the determination of the qualities of the stone. Let us now examine each of these characteristics.

1. DENSITY. The density of a material is the term by which we denote the quantity of matter it contains within a given surface, and is proportional to its specific gravity, or weight. Hence, by ascertaining the relative and specific weights of different materials, we have a measure of their density. The standard of comparison being pure water at a temperature of 60° Fahr. (15°.5 Cent.)

The density of a building material is to a certain extent a test of its compactness and durability.

2. HARDNESS. Relative hardness of different substances is determined by their relative powers of cutting and scratching. Amongst building materials the hardest substances, such as porphyry and siliceous grits 'strike fire,' or emit sparks when struck with the hammer, or pick.

For some purposes hardness is an important element in the selection of a building material, and in general the harder materials are the more durable. Experiments on the relative crushing weights of small cubes are frequently made when a very durable stone is required.

For decorative purposes, however, an excess of

hardness in a stone is objectionable, as it renders it more difficult and expensive for sculpturing and moulding. In estimating, therefore, the value of hardness in the selection of a material, it must be considered whether the structure (or portion of the structure) is to be of a massive, or of an ornamental, character.

3. STRUCTURE. The structure of rocks depends chiefly upon their mode of formation. Sedimentary rocks formed by the aqueous deposition of sand, clay, &c., over the bed of the sea, or an inland lake, have generally a laminated structure. The laminæ being parallel to the planes of bedding.

Laminated Structure. In placing the stone on its bed of masonry care should be taken that the planes of bedding occupy a horizontal position, and that the exposed surface is formed of a cross-section of the edges of the planes. The stone thus placed occupies in the artificial structure the position it occupied in nature, and is best protected from atmospheric disintegration.

Compact. So called, when the stone presents an uniform appearance without grains or plates; such as flint, basalt, &c.

Granular. When it is composed of visible grains, of greater or less size, united by a cementing material; such as many sandstones.

Oolitic. When composed of a multitude of little

spherules, generally hollow, resembling the roe of a fish. This structure is confined to limestones.

Crystalline. When formed of distinct crystals of the same, or different, minerals united into a solid mass. This structure is sometimes invisible to the naked eye in the case of many crystalline rocks, but is rendered apparent under the microscope. In granites, porphyries, and some marbles, the crystalline structure is easily discerned by the naked eye.

Saccharoid. When the structure and appearance resembles that of crystallized sugar; such as statuary marble.

Fibrous. When the stone appears as if composed of a number of fibres; such as a species of gypsum.

Cellular or *vesicular.* When containing numerous cavities; such as some kinds of lavas.

Schistose. When, owing to the internal structure and arrangement of the particles, the rock is capable of being split into laminæ, or slates, as in the case of clay-slate, which is due to 'slaty cleavage.' To this subject I have already referred (p. 287).

Concretionary. When the rock is formed of, or contains, concentric layers arranged generally round a nucleus. Large concretions, generally iron-stained, are frequently found amongst sandstone rocks, and are a source of much inconvenience and loss to the workmen. Such concretions are useless for building purposes, and are generally rejected by quarrymen.

4. Fracture. The character of this is indicated by the form of the surface when broken by a blow of the hammer. Thus there is the

Straight, or right, fracture, when the surfaces are planes;

Conchoidal, when the surfaces are curved, like the shell of a bivalve-mollusc. Compact stones generally break in this manner;

Hackly, when the surfaces are rough, or jagged.

5. Colour. The colour can be judged of by the eye; but care should be taken to note that of the internal portion of a stone which has not been acted upon by atmospheric influences, as well as the change (if any) which takes place in the colour where the surface is weathered.

The chief colouring material amongst the rocks is iron, and the kind of colour depends much on the state in which the iron exists in the stone.

Thus, blue and grey colours generally arise from the presence of iron as a carbonate, or protoxide; and stones which present this hue internally, when exposed generally turn yellow, or become iron-stained, owing to the chemical change which occurs from the action of the atmosphere; sesquioxide of iron is then formed.

Reddish stones—such as sandstones—generally retain their colour, the iron-pigment being in a state of sesquioxide.

The most pleasing colours for building purposes are pale yellow, or light red. Perfectly white stones are not the most agreeable to the eye.

Porphyries, and granites, generally retain their colour under exposure to the atmosphere.

Chemical Characters. The chemical constituents of rocks are of great importance in reference to their durability under certain circumstances of the atmosphere, and conditions of climate. Fortunately, it is by no means difficult, for ordinary purposes of construction, to ascertain with sufficient accuracy the presence, or absence, of special minerals.

The generality of building stones range themselves under the heads of sandstones and limestones; and the purest kinds of these rocks are those which contain the smallest amount of foreign ingredients.

But between these extreme cases, there are to be found a great variety of intermediate kinds of rocks, generally called 'calcareous sandstones,' in which the basis is composed of sand, or siliceous particles, with an intermixture of lime; or 'siliceous limestones,' in which the basis is carbonate of lime, with a proportion of siliceous material; and it is frequently of importance to ascertain whether a sandstone contains any, or a large, proportion of carbonate of lime. This is easily effected by the simple use of dilute hydrochloric, or nitric acid. If the stone contains carbonate of lime or magnesia, effervescence will ensue

upon the application of a small quantity of acid to the surface; and if the quantity of lime is very large, the effervescence will be proportionably brisk.

The presence of carbon—often in dark coloured marbles or limestones—may be ascertained simply by heating. If the mineral is present, it will then be driven off, and the stone will become of a lighter hue.[1]

Having thus presented the reader with a view of the physical and chemical characters of the more ordinary rocks, and the mode of determining them for general purposes, I shall pass on, in the next chapter, to make some observations on the selection of building materials with reference to climate and the nature of the atmosphere.

[1] This, however, may not always be a test of the presence of carbon, as there are other substances which are capable of giving a dark shade to rocks, and which would become pale when heated.

CHAPTER II.

ON THE SELECTION OF BUILDING STONES, WITH SPECIAL REGARD TO CLIMATE AND THE NATURE OF THE ATMOSPHERE.

The climate of countries where building stones are employed in modern times, may be conveniently divided into *dry* and *humid;* and as regards atmosphere, into *pure* and *smoky*, or *acid.* Rainless regions, being exceptional, may be dismissed with the remark that almost any kind of stone will be found durable in them. Passing, therefore, to the consideration of the subject under the heads above named, we commence with climates which may be called 'dry,' in which rain is only periodical.

Dry climates. In such climates the rain falls but sparingly, and only periodically; the greater part of the year being rainless, and the temperature warm. Countries which enjoy such climates are tropical or sub-tropical, and include portions of Central and Southern Europe, Asia Minor, India, Australia, and large tracts of Central America, both north and south of the Equator.

Such countries are especially favoured in the preservation of structures, even when composed of comparatively perishable materials; and examples have been already cited in these pages of the existence, in a remarkable state of freshness, of buildings of very ancient date. Thus in the Arch of Constantine, some of the statuettes and sculptured portions in marble preserve the sharpness of their outline; and even the more ancient monuments of Paestum, composed of calcareous travertine, are still standing. In India, ancient temples formed of laterite—a modern deposit of gravel cemented by lime—are still in perfect preservation. Such examples, and many more which might be produced, all go to prove that even in regions subjected to very heavy periodical rains, provided the air be pure, and free from acids, buildings of even friable and calcareous materials are capable of withstanding atmospheric disintegration for a lengthened period.

Rains which fall at long intervals, though with tropical violence, do not act so injuriously on stone structures as those less violent, but more frequent. In such countries, therefore, the chemical composition of a building stone becomes of minor importance. The architect will now be able to select the stone amongst those to which he has access, which is most agreeable to the eye, and presents the requisite physical characters as regards hardness, density, and

structure. All this, however, depends on the purity of the air and its freedom from smoke and acid fumes. Should these be present, the chemical composition becomes of first importance, and those principles of selection must then be adopted which are stated below.

Humid or wet climates. Under this head may be included the climates of such countries as the British Islands, the North-West of Europe, and those portions of North America washed by the Ocean. Such climates are the most trying and destructive to buildings of which the materials are of a porous structure, or contain large proportions of calcareous matter; and here chemical composition, structure, and density all become elements for consideration in the choice of a stone for buildings intended to be lasting.

The presence in such countries of smoke, of sulphurous, hydrochloric, and other acids, powerfully aids in the destructive effect of rain or moisture; for the rain itself takes up a considerable amount of the acid from the air, and spreads it over the exposed surfaces of the buildings.

The reader will scarcely need to be reminded that limestones and dolomites are especially subject to disintegration from the influence of rain charged with acid; and this country presents numerous unhappy examples of its effects. Of these perhaps the

cases of St. Mary Redcliffe's Church, in Bristol, the New Houses of Parliament, and Henry VII's Chapel in Westminster Abbey, are the most instructive examples; the first built of oolitic limestone, the second of dolomite, and the third of Caen stone—a white limestone of Normandy of Jurassic age. Even the portions of this exquisitely beautiful structure, restored with Bath Oolite about a quarter of a century ago, have given way before the influence of an atmosphere charged with smoke, and dripping with moisture throughout a large portion of the year.

For such climates, therefore, limestones, especially soft, granular, and porous kinds, should as far as possible be avoided, and even sandstones which contain a notable percentage of calcareous matter in the form of a cement.

The best kinds of building stone for smoky and wet climates are siliceous sandstones, formed of grains of quartz, cemented together by a siliceous or felspathic paste. In Great Britain such rocks are largely distributed amongst the Lower Carboniferous formation of Scotland, the North of England, and Wales; the materials of which they are composed being derived from the disintegrated gneissose and granitic rocks which formed the land of the period. Such rocks are almost indestructible, and have been used with good results in some of the large manufacturing and smoky towns, and cities, of those

districts where they occur. Being destitute of carbonate of lime or magnesia, or containing them only in very minute quantities, they are not exposed to the corroding action of the acids which pervade the air.

There is, indeed, a remarkable suitability in the distribution of building stones in Great Britain to the especial wants of different parts of the country. Thus amongst the mining and manufacturing districts of the centre of Scotland, and the north and centre of England, siliceous sandstones are plentifully developed in the Carboniferous and Triassic formations; while the soft calcareous stones of the Jurassic (or Oolitic) series are distributed amongst the comparatively smokeless districts of the south and east, where the purity of the atmosphere, and a less watery sky, admit of a lengthened duration for buildings constructed of such materials.

Whilst the principles here laid down are applicable to all climates and all lands, there is one observation which must be constantly borne in mind, and without which the application of general principles would be of no avail, that without due care in the selection of the stone in the quarry, there can be no security for the excellence of the material.

It is to the absence of this precaution, that the failure in many portions of the exposed surface of the New Houses of Parliament is generally attri-

buted. The magnesian limestone of which it is built is a rock which, in its natural state, is subject to frequent and rapid variations in mineral character, and while one portion of a bed may be firm and durable, a neighbouring portion may have opposite qualities. All other formations are subject to similar changes though often in a less degree, and in all cases the necessity of selection is more or less imperative. Even in such an ordinary occupation as the selection of a block of hewn stone from its rocky bed, excellence is only to be obtained; as in all other arts, by patient industry and observation. Nature has abundant favours to bestow upon those who seek them with humility and care. The zealous suitor is certain of his reward; but she has no honours in store for the negligent, or the slothful.

APPENDIX.

WEIGHTS PER CUBIC FOOT OF BRITISH BUILDING STONES.

[*From the 'Mineral Statistics of the United Kingdom,' by Mr. R. Hunt, F.R.S.* 1860 (*Part II*).]

THE following table has been constructed by Mr. C. H. Smith, who, as one of the Commissioners for selecting the stone for the Houses of Parliament, had already, in the Report furnished by them, published many results, which are here reprinted. Upon applying to that gentleman for some additional information, he most liberally undertook to construct a new and correct table, showing the weights of a cubic foot of specimens fairly representing all the varieties of building stones used in this country.

The various stones named may be considered as fair average samples of the material which each of the quarries respectively produces. In nearly all cases, the density, or avoirdupois weights, have been ascertained with two very accurately squared six-inch cubes (duplicates, equal to one-fourth of a cubic foot), weighed in the state in which stones are usually employed for masonry.

Name of Quarry.	Nearest Post Town.	County.	Avoirdupois Weight per Cubic Foot.		
			lbs.	oz.	dr.
Gatton..................	Reigate	Surrey	103	1	4
Tisbury	Tisbury	Wiltshire	111	2	4
Coombe Down Lodge	Bath	Somersetshire......	116	0	0
Totternhoe	Dunstable	Bedfordshire	116	8	0
Calverley...............	Tunbridge Wells ..	Kent	118	1	0
Windrush, soft	Burford	Oxfordshire........	118	2	12
Farleigh Down	Bath..............	Somersetshire	122	10	12
Box Hill	Chippenham	Wiltshire..........	123	0	0
Park Quarry	Tixall	Staffordshire	124	9	1
Park Quarry	Corby	Lincolnshire	125	11	0
Dundry Hill	Bristol............	Somersetshire......	126	2	2
Cadeby	Doncaster	Yorkshire	126	9	8
Aislaby	Whitby	"	126	11	0
Roach (Goslings) Portland	Weymouth	Dorsetshire........	126	13	13
Steetley (white)	Worksop..........	Nottinghamshire ..	128	3	0
Ketton	Ketton	Rutlandshire	128	5	12
Crawbank	Borrowstounness ..	Linlithgowshire	129	2	1
Old Down (Doulting)	Shepton Mallet	Somersetshire......	130	4	0
Morley Moor	Derby	Derbyshire	130	8	9
Steetly (yellow)	Worksop..........	Nottinghamshire ..	130	9	5
Heddon	Newcastle-on-Tyne .	Northumberland ...	130	11	12
Longannet	Kincardine	Perthshire	131	11	11
Beer....................	Axminster	Devonshire	131	12	0
Dunmore Stable..........	Falkirk	Stirlingshire	132	2	5
Bottom Bed (Goslings) Portland..............	Weymouth	Dorsetshire........	132	5	7
Duffield Bank............	Derby	Derbyshire	132	14	12
Hollington	Uttoxeter	Staffordshire	133	1	4
Castle's Quarry, Portland..	Weymouth	Dorsetshire........	133	6	7
Haydor	Sleaford	Lincolnshire	133	7	12
Moakery	Corby	"	133	8	0
Brodsworth..............	Doncaster	Yorkshire	133	10	8
Pensher	Houghton-le-Spring.	Durham	134	5	1
Vern Street, Portland	Weymouth	Dorsetshire........	134	10	1
Way Croft, Portland......	"	"	133	8	13
Humbie, dark	Edinburgh	Edinburgh	135	13	0
Gatherley Moor	Richmond	Yorkshire	135	13	9
Windrush, hard	Burford	Oxfordshire........	135	15	0
Hunger Hill	Belper............	Derbyshire	135	15	4
Taynton	Burford	Oxfordshire........	135	15	8
Sutton..................	Bridgend..........	Glamorganshire	136	0	0
Barnack	Stamford..........	Lincolnshire	136	12	5

Name of Quarry.	Nearest Post Town.	County.	Avoirdupois Weight per Cubic Foot. lbs.	oz.	dr.
Park Nook	Doncaster	Yorkshire	137	3	0
Duke of Hamilton's	....	Linlithgowshire	137	4	4
Hildenley	Malton	Yorkshire	137	10	7
Huddlestone	Sherburne	,,	137	13	8
Hawksworth Wood	Leeds	,,	137	14	12
Duke of Hamilton's	....	Linlithgowshire	138	2	0
Roche Abbey	Bawtry	Yorkshire	139	2	5
Ancaster	Sleaford	Lincolnshire	139	4	13
Redgate	Wolsingham	Durham	139	9	9
Meanwood	Leeds	Yorkshire	139	14	0
Scullcap, Portland	Weymouth	Dorsetshire	140	1	0
Humbie, light	Edinburgh	Edinburgh	140	3	8
Stanley	Bewdley	Shropshire	141	7	0
Catcraig	Borrowstounness	Linlithgowshire	141	11	0
Wass, soft	Thirsk	Yorkshire	141	11	1
Craigleith, bed rock	Edinburgh	Edinburgh	141	12	0
Ham Hill	Yeovil	Somersetshire	141	12	1
Bramley Fall	Leeds	Yorkshire	142	3	8
Stainton	Barnard Castle	Durham	142	8	5
Hookstone	Harrowgate	Yorkshire	142	10	0
Westwood	Leeds	,,	143	0	0
Giffneuk	Glasgow	Lanarkshire	143	14	13
Anston, Norfall Quarry	South Anston	Yorkshire	144	0	9
Anston, Stone-ends Quarry	,,	,,	144	3	8
Duke's Quarries	Cromford	Derbyshire	144	8	5
Kenton	Newcastle-on-Tyne	Northumberland	145	1	0
Victoria	Leeds	Yorkshire	145	3	8
Curf, Groove Quarry, Portland	Weymouth	Dorsetshire	145	9	9
Woodhouse	Mansfield	Nottinghamshire	145	12	4
Craigleith, liver rock	Edinburgh	Edinburgh	145	14	5
Gun Barrel	Bewdley	Shropshire	146	0	0
Mansfield, white	Mansfield	Nottinghamshire	146	9	0
Corby	Corby	Lincolnshire	146	11	8
Barbadoes	Chepstow	Monmouthshire	146	12	5
New Leeds	Leeds	Yorkshire	147	8	0
Grove, Portland	Weymouth	Dorsetshire	147	10	11
Darley Dale	Bakewell	Derbyshire	148	3	3
Warwick	Huddersfield	Yorkshire	148	10	8
Mansfield, red	Mansfield	Nottinghamshire	148	10	9
Amygdaloid	Crediton	Devonshire	149	9	5
Talacre	Holywell	Flintshire	150	4	4

Name of Quarry.	Nearest Post Town.	County.	Avoirdupois Weight per Cubic Foot.		
			lbs.	oz.	dr.
Seacombe	Purbeck	Dorsetshire	151	0	4
Park Spring	Leeds	Yorkshire	151	1	12
Chilmark, Trough Bed	Salisbury	Wiltshire	151	6	12
Hoyle House, Clough	Huddersfield	Yorkshire	151	7	1
Chilmark, Penney Bed	Salisbury	Wiltshire	151	9	5
Bolsover Moor	Chesterfield	Derbyshire	151	11	0
Elland Edge	Halifax	Yorkshire	153	4	9
Longwood Edge	Huddersfield	"	153	7	0
Crossland Hill	"	"	155	4	1
Ketton, Rag Bed	Ketton	Rutlandshire	155	10	13
Viney Hill	Coleford	Gloucestershire	155	11	12
Chilmark, Hard White Bed	Salisbury	Wiltshire	157	6	0
Scotgate Head	Huddersfield	Yorkshire	158	0	0
Hopton Wood	Wirksworth	Derbyshire	158	7	4
Lochee	Dundee	Forfarshire	158	11	0
Auchray	"	"	158	14	5
Lioch	"	"	159	3	1
Knockley	Coleford	Gloucestershire	159	5	4
Mylnefield	Dundee	Forfarshire	160	0	13
Munlochy	Munlochy	Ross-shire	160	9	11
Glammiss	Forfar	Forfarshire	161	2	8
Wass, Hard Bed	Thirsk	Yorkshire	162	8	0
Pyotdykes	Dundee	Forfarshire	162	8	13
Granite, Sterling Hill	Peterhead	Aberdeenshire	165	14	5
Granite, High Rock, Breadalbane	....	Perthshire	166	0	9
Dylais	Swansea	Glamorganshire	166	3	12
Kentish Rag	Maidstone	Kent	166	9	9
Black Hill, Granite	Stirling	Stirlingshire	166	10	4
Abercarne	Newport	Monmouthshire	167	15	5
Trebaunwa	Swansea	Glamorganshire	168	1	9
Red Jacket	"	"	168	2	8
Granite, Dalkey	Dublin	Dublin	169	9	7
Granite, Bars, Breadalbane	....	Perthshire	169	11	5
Cenfas	Swansea	Glamorganshire	170	2	4
Mumble	"	"	170	7	0
Black Marble	Kilkenny	Ireland	171	6	0
Tiree Marble	Hebrides	Scotland	172	5	0

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